PB89-136592

INCINERATION OF SEWAGE SLUDGE TECHNICAL SUPPORT DOCUMENT

(U.S.) Environmental Protection Agency
Washington, DC

1988

U.S. Department of Commerce
National Technical Information Service
NTIS

PB89-136592

United States
Environmental Protection
Agency

Office of Water
Regulations and Standards
Washington, DC 20460

EPA

Water

TECHNICAL SUPPORT DOCUMENT

Incineration of Sewage Sludge

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL
INFORMATION SERVICE
SPRINGFIELD, VA 22161

NOTICE

THIS DOCUMENT HAS BEEN REPRODUCED FROM THE BEST COPY FURNISHED US BY THE SPONSORING AGENCY. ALTHOUGH IT IS RECOGNIZED THAT CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE.

50272-101

REPORT DOCUMENTATION PAGE

1. REPORT NO.

2.

3. Recipient's Accession No.

4. Title and Subtitle

Incineration of Sewage Sludge
Technical Support Document

5. Report Date

6.

7. Author(s) U.S. Environmental Protection Agency
Office of Water Regulations and Standards

8. Performing Organization Rept. No.

9. Performing Organization Name and Address

U.S. Environmental Protection Agency
Office of Water Regulations and Standards
401 M Street, SW
Washington, DC 20460

10. Project/Task/Work Unit No.

11. Contract(C) or Grant(G) No.

(C)

(G)

12. Sponsoring Organization Name and Address

U.S. Environmental Protection Agency
Office of Water Regulations and Standards
401 M Street, SW
Washington, DC 20460

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstract (Limit: 200 words)

This document contains information to support the numeric limits proposed in the regulations for sewage sludge incineration for the metals: arsenic, beryllium, cadmium, chromium, lead, mercury, and nickel, and total hydrocarbons (THCs). For THCs, the numeric limit is a stack combustion gas concentration, based on allowable ambient air quality at ground-level, site characteristics, and meteorological conditions. The limits for metals are allowable sludge concentrations, based on allowable ambient air quality at ground-level, allowable emission rates, air dispersion factors, and data on facility operating conditions.

A major process in determining the limits was the risk methodology. In the methodology, cancer potency values were applied and risk levels were developed based on worst-case emission and exposure scenarios. Air dispersion models were used in the methodology to predict the maximum emission levels. They were also used to develop a simplified approach for determining compliance with the metal and THC limits.

The data to support the regulations were obtained from a telephone survey of incinerator facilities and a literature search. The most widely used technologies include multiple-hearths, fluidized-beds, and electric furnaces. Wet scrubbing is the most commonly used pollution control system.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms

c. COSATI Field/Group

18. Availability Statement

To Be Released To The Public

19. Security Class (This Report)

20. Security Class (This Page)

21. No. of Pages

22. Price

(See ANSI–Z39.18) See Instructions on Reverse OPTIONAL FORM 272 (4–77)
(Formerly NTIS–35)
Department of Commerce

PREFACE

Section 405(d) of the Clean Water Act requires the U.S. Environmental Protection Agency (EPA) to develop and issue regulations that identify:

- Uses for sludge, including various means of disposal
- Factors, including costs, which must be considered when determining the measures and practices applicable to each use or disposal method
- Pollutant concentrations that interfere with each use or disposal method

To comply with this statutory mandate, EPA has embarked on a program to develop five major technical regulations: land application, distribution and marketing; monofilling; surface impoundment; incineration; and reduction of pathogens and vector attraction. EPA has also proposed regulations governing the establishment of State sludge management programs, which will implement both existing and future criteria (40 CFR 501).

The principal goal of the proposed incineration regulation is to protect human health and the environment. Included in this proposed regulation are provisions to protect air from the potentially deleterious effects of incinerating sewage sludge. This document provides the technical background and justification for the provisions contained in Subpart E of the proposed regulation.

Public comment on the technical adequacy and scientific validity of this document as well as the requirements contained in the proposed regulation should be submitted during the public comment period. Any questions related to this document may be directed to:

Eugene P. Crumpler
U.S. Environmental Protection Agency
Wastewater Solids Criteria Branch (WH-585)
Criteria and Standards Division
Office of Water Regulations and Standards
Washington, DC 20460
202-475-7313

Martha Prothro, Acting Director
Office of Water Regulations

TABLE OF CONTENTS

Page

LIST OF TABLES vii

LIST OF FIGURES viii

LIST OF UNITS AND ACRONYMS x

1. INTRODUCTION 1-1

    1.1 Definition of Sludge Incineration 1-1
    1.2 Overview of the Sludge Incineration Numeric Limits 1-1
        1.2.1 Allowable Sludge Concentrations, Stack Concentrations, and Risk Specific Doses (RSDs) 1-2
        1.2.2 Air Dispersion Models and Incinerator Databases 1-3
        1.2.3 Control Efficiencies and Air Emissions Control Databases 1-4
    1.3 Contents of the Technical Support Document 1-4

2. SEWAGE SLUDGE INCINERATION TECHNOLOGY 2-1

    2.1 Current Furnace Technology 2-1
        2.1.1 Multiple-Hearth Furnaces 2-2
        2.1.2 Fluidized-Bed Incinerators 2-6
        2.1.3 Electric Furnaces 2-9
    2.2 Air Pollution Control Systems 2-13
        2.2.1 Wet Scrubbers 2-13
        2.2.2 Electrostatic Precipitators (ESPs) 2-19
        2.2.3 Fabric Filters 2-23
        2.2.4 Afterburners 2-26
    2.3 Ash Management 2-29

3. DEVELOPMENT OF DATA BASE FOR SLUDGE INCINERATORS 3-1

    3.1 Incinerator Population Database 3-1
    3.2 Air Emissions Control Efficiency Database 3-2
        3.2.1 Development and Scope of the Database 3-6
        3.2.2 Compilation of the Database 3-9

4. DESCRIPTION OF THE AIR DISPERSION MODELS 4-1

    4.1 Model Selection 4-1

TABLE OF CONTENTS (Continued)

Page

- 4.2 Model Descriptions 4-3
  - 4.2.1 ISCLT Model 4-3
  - 4.2.2 LONGZ Model 4-3
  - 4.2.3 COMPLEX I Model 4-3
- 4.3 Model Comparison Tests 4-4
- 4.4 ISCLT Sensitivity Analysis 4-4
  - 4.4.1 First Sensitivity Analysis 4-5
  - 4.4.2 Second Sensitivity Analysis 4-5
  - 4.4.3 Third Sensitivity Analysis 4-6
  - 4.4.4 Conclusions of Sensitivity Analysis 4-7
- 4.5 Good Engineering Practice Stack Height (40 CFR 51.1(ii)) 4-7

5. RISK METHODOLOGY FOR INCINERATION 5-1

- 5.1 Methodology Summary and Scope 5-1
  - 5.1.1 Pathway Evaluated 5-3
  - 5.1.2 Model Plants Database 5-3
  - 5.1.3 Air Dispersion Models 5-4
  - 5.1.4 Exposure, Dose, Risk and Cancer Potency Criteria 5-6
  - 5.1.5 Risk-Specific Dose (RSD) 5-10
  - 5.1.6 Example Calculation to Determine Sludge Concentrations 5-11
- 5.2 Comments and Responses on the Sludge Incineration Methodology 5-12
  - 5.2.1 The LONGZ Model Predictions of Concentrations Above Stack Heights 5-13
  - 5.2.2 Model Predictions of Nonsteady Incinerator Operations 5-14
  - 5.2.3 Consideration of Particulate Emissions 5-14
  - 5.2.4 Model Inclusion of Air Pollution Control Devices 5-15
  - 5.2.5 Consideration of Ecosystem on Secondary Human Impacts 5-15

6. DEVELOPMENT OF RISK-SPECIFIC DOSES (RSDs) 6-1

- 6.1 RSD Calculation for Carcinogens 6-2
  - 6.1.1 Sample RSD Calculation for Carcinogens 6-2
  - 6.1.2 Nickel and Chromium 6-3
- 6.2 RSD Calculation for Lead 6-5
- 6.3 Mercury and Beryllium 6-6

TABLE OF CONTENTS (Continued)

Page

6.4 RSDs for Total Hydrocarbons 6-7
  6.4.1 THC Cancer Potency Value 6-7
  6.4.2 Conversion of Cancer Potency Values to RSDs 6-13

7. DEMONSTRATING COMPLIANCE WITH ALLOWABLE SLUDGE CONCENTRATIONS FOR METALS 7-1

7.1 Basic Equation for Determining Compliance 7-1
  7.1.1 Reasonable Worse-Case Control Efficiencies 7-2
7.2 Specialized Equations for Mercury, Beryllium, and Lead 7-5
  7.2.1 Mercury and Beryllium 7-5
  7.2.2 Lead 7-7
7.3 Simplified Approach 7-7
  7.3.1 Simplified Air Modeling Procedure 7-7
7.4 Site Specific Determinations 7-14
  7.4.1 Site-Specific Air Dispersion Models 7-14
  7.4.2 Site-Specific Control Efficiencies 7-14

8. REGULATION OF ORGANIC POLLUTANTS 8-1

8.1 Tests of the Destruction Efficiencies of Organics 8-1
  8.1.1 Test Results and Discussion 8-2
8.2 Determination of Allowable Stack Emission Rates for THC 8-8
  8.2.1 THC Dispersion Factor 8-8
  8.2.2 Combustion Gas Flow 8-9
  8.2.3 FID Measurement of THC Concentration 8-15
  8.2.4 Conversion of the THC RSD to a Site-Specific Stack Concentration 8-17

9. INCINERATOR MANAGEMENT PRACTICES 9-1

9.1 Temperature Limitations 9-2
  9.1.1 Minimum Temperature 9-2
  9.1.2 Maximum Temperature 9-3
9.2 Excess Air Rate 9-7
  9.2.1 Minimum Excess Air Rate 9-8
  9.2.2 Maximum Excess Air Rate 9-8
9.3 Sludge Feed Rate 9-11
9.4 Air Pollution Control Systems 9-13
  9.4.1 Wet Scrubbers 9-13
  9.4.2 Electrostatic Precipitators 9-14
  9.4.3 Fabric Filter Baghouses 9-15

TABLE OF CONTENTS (Continued)

Page

10. REFERENCES 10-1

APPENDIX A SLUDGE INCINERATOR POPULATION DATABASE

APPENDIX B RISK ASSESSMENT METHODOLOGY FOR SLUDGE INCINERATION

APPENDIX C ISCLT MODEL SENSITIVITY ANALYSIS

APPENDIX D BACKGROUND INFORMATION ON THE RISK OF PIC EMISSIONS FROM SEWAGE SLUDGE INCINERATORS

APPENDIX E STATISTICAL ANALYSIS OF SLUDGE INCINERATOR EMISSIONS

APPENDIX F REGRESSION RESULTS AND PLOTS OF EMISSION RATES FOR METALS AND SELECTED ORGANIC POLLUTANTS

LIST OF TABLES

Table No.	Title	Page
Table 2-1	Air Pollution Control Systems by Furnace Type, From Telephone Survey Database	2-14
Table 3-1	Literature Studies Reviewed for Air Emissions Control Data Base Development	3-7
Table 3-2	Summary of Incineration Information Evlauted for Emission Control Database	3-10
Table 5-1	Relevant Parameters for the Ten Modeled Sludge Incinerator Facilities	5-5
Table 5-2	Cancer Potency Values for Metals (q_1*)	5-9
Table 6-1	95th Percentile Concentrations of the C_1 and C_2 Fractions: (Generic Risk Calculations with Two Significant Figures)	6-9
Table 7-1	Descriptive Statistics on Mean Incinerator Removal Efficiencies Across Incinerator and Reference Document	7-4
Table 7-2	10th Percentiles of Pollutant Control Efficiencies	7-6
Table 7-3	Summary of Modeling Runs to Determine Worst Case Dispersion Factors for the Simplified Air Modeling Approach	7-9
Table 7-4	Selected Worst Case Dispersion Factors from Figure 7-1	7-11
Table 7-5	Dispersion Factors	7-13
Table 8-1	Organics Identified in 1987 Sludge Incinerator Testing and Their Destruction Efficiencies	8-3
Table 8-2	Summary of Emissions Data from 1987 Incinerator Tests	8-4
Table 9-1	Metals Control Efficiencies for Four Sludge Incinerators Tested in 1987	9-9

LIST OF FIGURES

Figure No.	Title	Page
Figure 2-1	Cross-Section of a Typical Multiple-Hearth Incinerator	2-3
Figure 2-2	Cross-Section of a Fluidized-Bed Furnace	2-7
Figure 2-3	Process Flow Diagram: Infrared Incinerator System	2-11
Figure 2-4	Cross-Section of a Venturi/Impingement-Tray Scrubber	2-16
Figure 2-5	Typical Layout for Spray Tower	2-18
Figure 2-6	Typical Cyclonic Dust Collector	2-20
Figure 2-7	Schematic of an Electrostatic Precipitator	2-21
Figure 2-8	Example of a Large Fabric Filter	2-25
Figure 3-1	Distribution of Capacity for 127 Sludge Incinerator Sites	3-3
Figure 3-2	Distribution of Stack Heights for Sludge Incinerators	3-4
Figure 3-3	Distribution of Stack Exit Gas Velocities for Sludge Incinerators	3-5
Figure 7-1	Dispersion Factors from ISCLT Sensitivity Analysis Model Runs	7-10
Figure 7-2	Selected Worst-Case Dispersion Factors from Table 7-4	7-12
Figure 8-1	Total Hydrocarbon Concentration (THC) vs. Total Organics Concentration of Volatiles and Semi-volatiles Detected in Test Run	8-7
Figure 8-2	Basic Circuit of the Flame Ionization Detector	8-16

LIST OF FIGURES (Continued)

Figure No.	Title	Page
Figure 9-1	Regression Analysis of Percent of Arsenic Emitted versus Incineration Combustion Temperatures	9-4
Figure 9-2	Regression Analysis of Percent of Cadmium Emitted versus Incineration Combustion Temperatures	9-5
Figure 9-3	Regression Analysis of Percent of Lead Emitted versus Incineration Combustion Temperatures	9-6
Figure 9-4	Lead Control Efficiency vs. Excess Air Rate	9-10

LIST OF UNITS AND ACRONYMS

APCS	air pollution control system
Btu	British thermal unit
BW	body weight
°C	Celsius
C	carbon
C	allowable sludge concentration
C_1	methane
C_2s	ethane, ethylene, acetylene
CAG	Cancer Assessment Group
CaOh	calcium hydroxide, lime
CE	overall system control efficiency
CEM	continuous emissions monitoring
CF	conversion factor
CFR	Code of Federal Regulations
CGF	flow of combustion gases from the incinerator
CO_2	carbon dioxide
Cr^{+3}	chromium, noncarcinogenic trivalent state
Cr^{+6}	chromium, highly carcinogenic hexavalent state
CWA	Clean Water Act
DF	dispersion factor
dl	deciliter
DMT	dry metric tons
ECAO	Environmental Criteria Assessment Office
EPA	Environmental Protection Agency
ER	emission rate
ESP	electrostatic precipitator
°F	Fahrenheit

FBI	fluidized-bed furnace
FE	fraction emitted
FGF	fuel gas flow rate of combustion gases
FID	flame ionization detector
FR	daily fuel usage based on annual usage, and feed rate
ft	foot
ft^2	square foot
g	gram
GEP	good engineering practices
H	hydrogen
H	height of structures nearby to incinerator stacks
H_2O	water
Hg	mercury
H_g	good engineering practice stack height
hr	hour
I_a	inhalation rate
in	inch
IRIS	Integrated Risk Information System
ISCLT	Industrial Source Complex Long Term (Model)
°k	Kelvin
kcal	kilocalorie
kg	kilogram
km	kilometer
kPa	kilopascal
kV	kilovolt
l	liter
L	lesser dimension, height, or projected width of structures nearby to incinerator stacks
lb	pound

m^3	cubic meter
M5	EPA Method 5 for particulates
M12	EPA method 12 for metals
MEI	most exposed individual
mg	milligram
Mg	megagram (metric ton)
MHF	multiple-hearth furnace
ml	milliliter
MM5	Modified EPA method 5 for particulates
MSW	municipal solid waste
mt	metric ton
N_2	nitrogen gas
NAAQS	National Ambient Air Quality Standard
ND	nondetections
NESHAP	National Emission Standard Hazardous Air Pollutant
ng	nanogram
NG	natural gas
NSPS	New Source Performance Standards
O_2	oxygen
OW	Office of Water
%	percent
PIC	products of incomplete combustion
POTW	Publicly Owned Treatment Works
ppm	parts per million
psig	pounds per square inch gauge
Q_1	individual potency value
q_1*	cancer potency value
R^2	correlation coefficient
RCRA	Resource Conservation and Recovery Act
RL	risk level
RSD	risk specific dose

SASS	Source Assessment Sampling System for particulates
SC	stack concentration limit, and allowable sludge concentration
SCF	maximum combustion gas flow rate from sludge combustion
sec	second
SF	maximum daily sludge feed rate
SIP	State Implementation Plan
STAR	Stability Array
t	ton
TCPD	tetrachlorinated paradioxins
THC	total hydrocarbon
u	micron
ug	microgram
um	micrometer
VEHC	average heating value of the volatile fraction of the sewage sludge
VF	average volatile fraction of sludge solids
VOST	volatile organic sampling train
WEP	wet electrostatic precipitator
WERL	Water Engineering Research Laboratory
WG	water gauge
yr	year

SECTION ONE

INTRODUCTION

1.1 DEFINITION OF SLUDGE INCINERATION

Incineration is the burning of volatile materials in sludge solids in the presence of oxygen. Technically, incineration is not a sludge disposal or use method, but rather a treatment method that converts sludge into an ash, which is then disposed of or used. Nevertheless, because sludge incineration drastically reduces the volume and mass of residual solid materials, it has traditionally been regarded as a disposal method. As such, in the proposed regulation, this method is evaluated as a use/disposal option, just as land application, distribution and marketing, monofilling, and sewage sludge surface disposal methods are evaluated.

Of the thermal processes by which sludge can be broken down or treated, incineration is the only method widely used today. Currently applied to 20% of the nation's wastewater sludge, incineration has proved to be an effective sludge disposal technique. Recent experience has shown that if modern energy recovery technology and efficient operating techniques are used to deal with sludge consistency and volume, incineration of wastewater sludge can be an affordable and competitive sludge disposal alternative, even in older facilities.

1.2 OVERVIEW OF THE SLUDGE INCINERATION NUMERIC LIMITS

The proposed regulation sets forth allowable sludge concentrations for the metals arsenic, beryllium, cadmium, chromium, lead, and nickel. To regulate organic constituents, allowable stack emission concentrations are set forth for total hydrocarbons (THCs). The THC concentration is representative of the total organic matter emitted during the incineration combustion process. In effect, the THC measurement is used as a surrogate for all organics.

In addition to issuing allowable sludge and stack emission concentrations, the regulation also includes provisions for determining site-specific allowable limits.

1.2.1 Allowable Sludge Concentrations, Stack Concentrations, and Risk-Specific Doses (RSDs)

For metals, the allowable sludge concentrations are determined using:

- The allowable increase in ambient air quality at ground-level, or risk-specific dose (RSD)
- Air dispersion factors
- Sludge feed rates
- The emission control efficiency of the facility

For THCs, the allowable stack concentration (vol/vol) is based on:

- An RSD
- Stack height and other physical characteristics of the site
- Meteorological conditions of the site

For determining the ambient air concentrations or RSDs, a worst-case scenario was developed for a Most Exposed Individual (MEI). In the scenario, the MEI resides at the point of highest ground-level concentration, based on estimates from air dispersion models, and is exposed outdoors, 24 hours (hr) per day for 70 years (yr). The MEI absorbs 100% of all pollutants inhaled. The RSDs are calculated using specific risk levels and cancer potency values determined by EPA's Cancer Assessment Group (CAG).

For mercury and beryllium, EPA is using the National Emission Standards for Hazardous Air Pollutants (NESHAPs) values as the allowable emission rates for sludge incineration, based on previous calculations conducted by the Agency. For lead, the allowable increase in ambient air quality has been set at 25% of the National Ambient Air Quality Standard (NAAQS).

1.2.2 Air Dispersion Models and Incinerator Database

Atmospheric dispersion modeling was used to develop dispersion factors, which are major parameters used to determine the allowable sludge concentrations for metals and stack emission rates for THCs. The models were also used to estimate allowable ground-level concentrations at a large number of points in the vicinity of the incinerator stack, as part of the development of the reasonable worst-case scenario. By inspection, the maximum ground-level concentrations can be identified for each pollutant at one or more of these locations. The point of maximum emission becomes the location of the MEI.

Three EPA approved air dispersion models were evaluated for developing this regulation. The Industrial Source Complex Long Term (ISCLT) model is intended for urban and rural situations where terrain elevations do not exceed the stack height. It is the only model evaluated that considers the effect of building downwash, which is likely to be significant for many sludge incinerators with short stacks. The LONGZ and COMPLEX I models are more appropriate for use in complex terrain situations where terrain elevations exceed stack height. LONGZ is intended for complex urban terrain, while COMPLEX I is intended for complex rural terrain. All three models require data on incinerator specifications, the surrounding terrain, and meteorology.

In calculating the numeric limits, the ISCLT model was used because of its ability to simulate building downwash. Because the location of the MEI for facilities with significant downwash tends to be close to the incinerator, the inability of the ISCLT model to simulate complex terrain accurately was not considered a serious drawback. Comparison of the models indicated that the ISCLT model predicts higher concentrations then the LONGZ or COMPLEX I models, even in complex terrains.

1.2.3 Control Efficiencies and Air Emissions Control Database

Control efficiencies were used to determine allowable sludge concentrations for metals. These values relate to sludge feed rates and how efficient the incinerator systems are in preventing the metals from being emitted out of the stack. Incinerator control efficiencies were determined using a comprehensive literature search of incinerator emission tests. The literature was reviewed to determine control efficiencies of a number of incinerators equipped with a variety of control devices for the major pollutants of concern.

1.3 CONTENTS OF THE TECHNICAL SUPPORT DOCUMENT

For an overview of the regulation, refer to the section above.

Section 2 of this document describes the major sludge incinerator technologies currently applied in the United States. It contains information on the design characteristics and operating conditions of several furnace types, and air pollution control systems. Ash management practices are also discussed.

The Incinerator Population and Air Emission Control Efficiency databases used for conducting the risk methodology and the air dispersion modeling are described in Section 3.

Section 4 describes and compares the air dispersion models evaluated for the regulations. The section also discusses the sensitivity analysis conducted on the ISCLT model to determine how the model is used for a simplified modeling technique in developing numeric limits for metals.

A summary of the risk methodology used to develop the regulation is contained in Section 5. The basis for the RSD exposure and dose estimations, risk levels, and cancer potency values are discussed. Also contained in this section is a summary of the comments made by the Scientific Review Board about the risk methodology.

Section 6 more fully discusses the development of the RSDs. Sample calculations for determining the RSDs for carcinogens and noncarcinogens are contained in this section. An explanation of how the cancer potency value for THC was developed is also included.

Sections 7 and 8 include demonstrations of how to comply with the metal and THC numeric limits, respectively. Control efficiencies, dispersion factors, site-specific tests, and performance test requirements are discussed for metals. Combustion gas flow factors and monitoring methods are discussed in relation to compliance with the numeric limits for THCs.

Incinerator management practices for compliance with the limits are discussed in Section 9. The section contains information on minimum and maximum operating temperatures, excess air rates and sludge feed rate factors, and air pollution control system option

The appendices contain more detailed information on the databases, modeling sensitivity analysis, risk methodology, and metals and organics emissions tests used to develop the proposed regulations.

Cross-referencing is included throughout the document to facilitate the location of information.

SECTION TWO

SEWAGE SLUDGE INCINERATION TECHNOLOGY

This section describes the major sludge incinerator technologies currently applied in the United States. The design characteristics and operating conditions of multiple-hearth furnaces, fluidized-bed incinerators and electric furnaces are discussed. Air pollution control systems, including a variety of wet scrubber devices, electrostatic precipitators, afterburners, and fabric filters, and ash management practices are also addressed in this section.

2.1 CURRENT FURNACE TECHNOLOGY

The three major incinerator furnace technologies currently used in the United States to incinerate sludge from publicly owned treatment works (POTWs) are:

- Multiple hearth furnace (MHF)
- Fluidized-bed incinerator (FBI)
- Infrared (electric) furnace

In addition, POTW sludge is being coincinerated in several municipal solid waste facilities.

In early 1985, the EPA's Office of Air Quality Planning and Standards conducted a telephone survey to compile a database on POTW incinerator sites, on an estimated 80% or more of all the operational POTW incinerators in the United States. The survey database revealed that the 127 sites comprise a total of 227 incinerators of the following types:

- 192 multiple-hearths

- 23 fluidized-beds
- 5 electric (infrared) furnaces
- 7 coincinerators at solid waste facilities
- The total capacity of all of the 227 incinerators is 8,175 dry metric tons (mt) of sludge per day. The average capacity is 35 dry metric tons per day.

Refer to Section 3 and Appendix A for more information on this database. A description of each technology follows.

2.1.1 Multiple-Hearth Furnaces

The basic MHF design, initially developed for roasting mineral ores, is nearly a century old. Since the 1930s, an air-cooled variant of the original Herreshoff design has been used for incinerating sewage sludges.

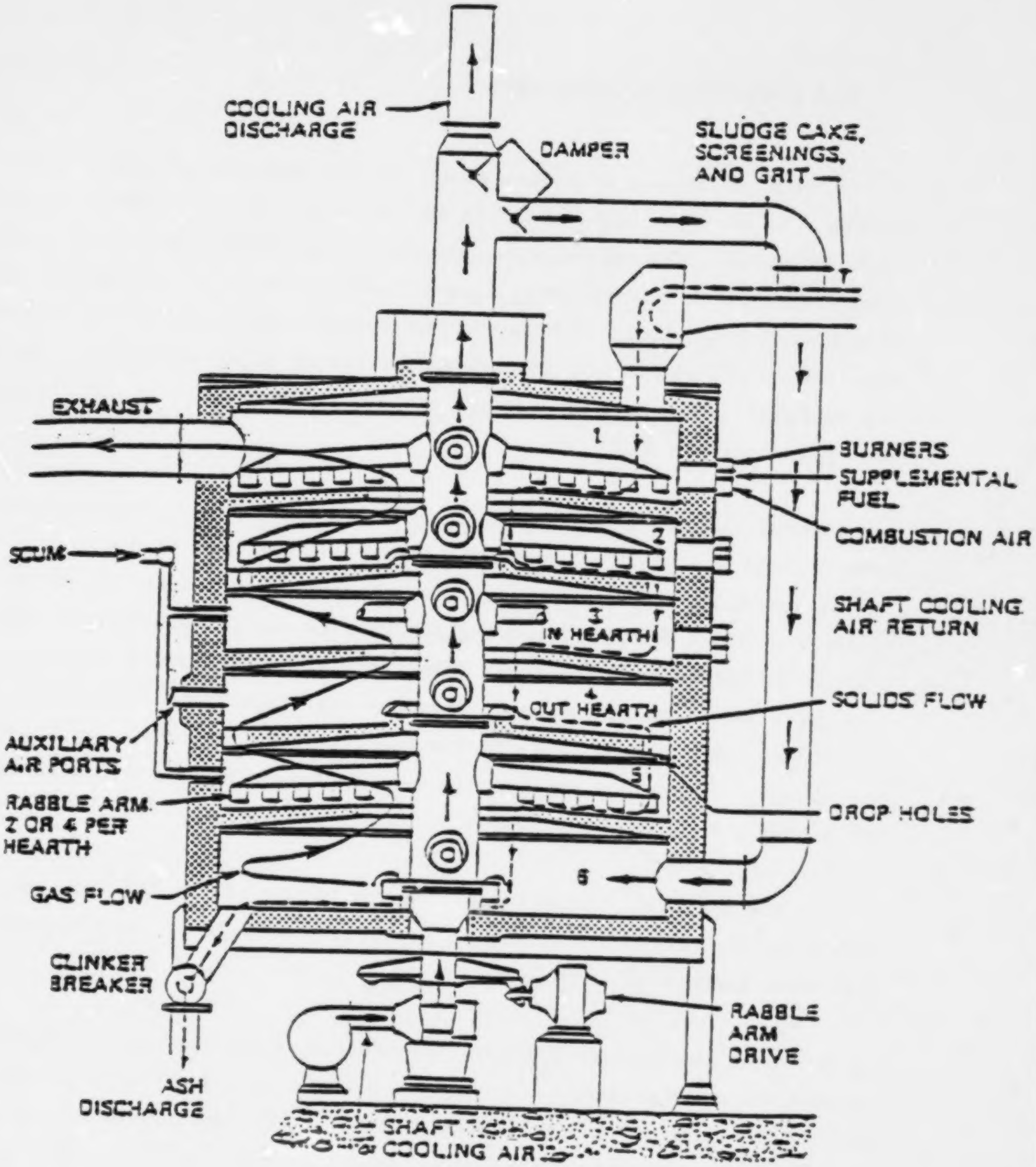
2.1.1.1 Design Characteristics

Figure 2-1 illustrates the overall design of a typical multiple-hearth furnace. MHF units are cylindrically shaped and oriented vertically. The outer shell is constructed of steel and surrounds a series of horizontal refractory hearths. A hollow cast iron rotating shaft runs through the center of the hearths. A fan located at the base of the shaft allows for the introduction of cool air into the shaft.

Attached to the central shaft are rabble arms that extend above the hearths. The rabble arms are shaped to rake the sludge in a spiral motion, alternating in direction from the outside in, and then to the inside out, between the hearths. Burners that provide auxiliary fuel are located in the sidewalls of the hearths.

MHFs used for incineration of sewage sludge typically range in size from 6-hearth furnaces, having an outer diameter of approximately 6 ft and a total

FIGURE 2-1. Cross-Section of a Typical Multiple-Hearth Incinerator


COOLING AIR DISCHARGE
DAMPER
SLUDGE CAKE, SCREENINGS, AND GRIT
EXHAUST
1
BURNERS
SUPPLEMENTAL FUEL
2
COMBUSTION AIR
SCUM
3
IN HEARTH
SHAFT COOLING AIR RETURN
4
OUT HEARTH
SOLIDS FLOW
AUXILIARY AIR PORTS
5
RABBLE ARM 2 OR 4 PER HEARTH
DROP HOLES
GAS FLOW
6
CLINKER BREAKER
RABBLE ARM DRIVE
ASH DISCHARGE
SHAFT COOLING AIR

effective hearth area of 85 ft^2, to 12-hearth furnaces, 22 ft in diameter, with hearth areas of over 3,000 ft^2. Hearth loading rates range from 7-12 $lb/hr/ft^2$ of wet sludge. This amount corresponds to furnace capacities of 600 lb up to 18 T/hr of wet sludge.

2.1.1.2 Operating Characteristics

In MHFs, partially dewatered sludge is fed into the periphery of the top hearth. To break up solid material and allow for better surface contact with heat and oxygen, the rabble arms rake the sludge toward the center shaft. The sludge then drops through holes located near the edge of the hearth. In the next hearth, the sludge is raked in the opposite direction. This process is repeated in all subsequent hearths as the sludge dries and burns. The hearths are designed so that a sludge depth of 1 in is maintained in each hearth at the optimal sludge flow rate.

Ambient air is ducted through the central shaft and its associated rabble arms to cool the shaft. A portion, or all, of this air is then taken from the top of the shaft and recirculated into the lower-most hearth as preheated combustion air. The shaft cooling air that is not circulated back into the furnace is ducted into the stack downstream of the air pollution control devices. Before being exhausted from the top hearth, the combustion air flows upward through the drop holes in the hearths, counter-current to the flow of the sludge. Provisions are usually made to inject ambient air directly into one of the middle hearths as well.

Dry ash is usually discharged from the bottom of the MHF unit and is either handled dry or is wetted to facilitate disposal. Ash management is discussed further in Section 2.3.

Based on the overall incineration process, multiple-hearth furnaces can be divided into three zones. The upper hearths comprise the drying zone where most of the moisture in the sludge is evaporated. During the drying process, the sludge temperature in this zone rises from 800-1,400°F. Combustion occurs in the middle hearths, or second zone, as the temperature is increased to about 1,500-1,600°F. The combustion zone can be further subdivided into the upper-middle hearths, where the volatile gases and solids are burned, and the lower-middle hearths, where most of the fixed carbon is combusted. The third zone, made up of the lower-most hearth(s), is the cooling zone. In this zone, the ash is cooled as its heat is transferred to the incoming combustion air.

"Excess air" is the amount of air required by a system to completely oxidize and convert carbon and hydrogen to water and carbon dioxide, due to inherent operational factors of the system which differ from theoretical conditions. Under optimal operating conditions in an MHF, 50-100% excess air must be added to ensure complete combustion of the sludge. Besides enhancing contact between fuel and oxygen in the furnace, adding excess air at these relatively high rates is necessary to compensate for normal variations in both the organic characteristics of the sludge feed and the rate at which the sludge enters the incinerator. When an inadequate amount of excess air is available, only partial oxidation of the carbon occurs with a resultant increase in emissions of carbon monoxide, soot, and hydrocarbons. Too much excess air, on the other hand, can cause increased entrainment of particulates and unnecessarily high auxiliary fuel consumption.

The rate at which the sludge cakes are fed into the hearths and the sludge cake moisture content must also be considered during the operation of a multiple-hearth sewage sludge incinerator. Any sudden increase or decrease in the load to the furnace can severely affect the performance of the incinerator. A sharp increase in the feed rate generally causes the burning zone to drop to lower hearths, a change that can lead to a decrease in temperature within the combustion zone and high auxiliary fuel usage. Conversely, a sudden decrease in furnace load can cause excessively high temperatures in the furnace with the attendant risk of damage to the refractors and rabble castings. The moisture content of the sludge feed must also be kept relatively constant for the same reasons.

For optimum performance, the temperature profile within the furnace should be controlled by adjusting the firing rate of the burners. Ideally, only those burners located immediately above and below the combustion zone should be used, depending on the number of hearths and the capacities of the available burners. This arrangement allows a greater sludge residence time in the drying zone and can decrease turbulence in the upper hearths.

Theoretically, combustion can become self-sustaining in an MHF and no auxiliary fuel needs to be added when sludges having a volatile fraction heating value of at least 10,000 Btu/lb, a solids content of 25% or greater, and a volatile solids fraction of at least 60-65% are burned. In practice, however, few MHFs are operated autogenously. Most of these units use auxiliary fuel, either natural gas or oil.

2.1.2 Fluidized-Bed Incinerators

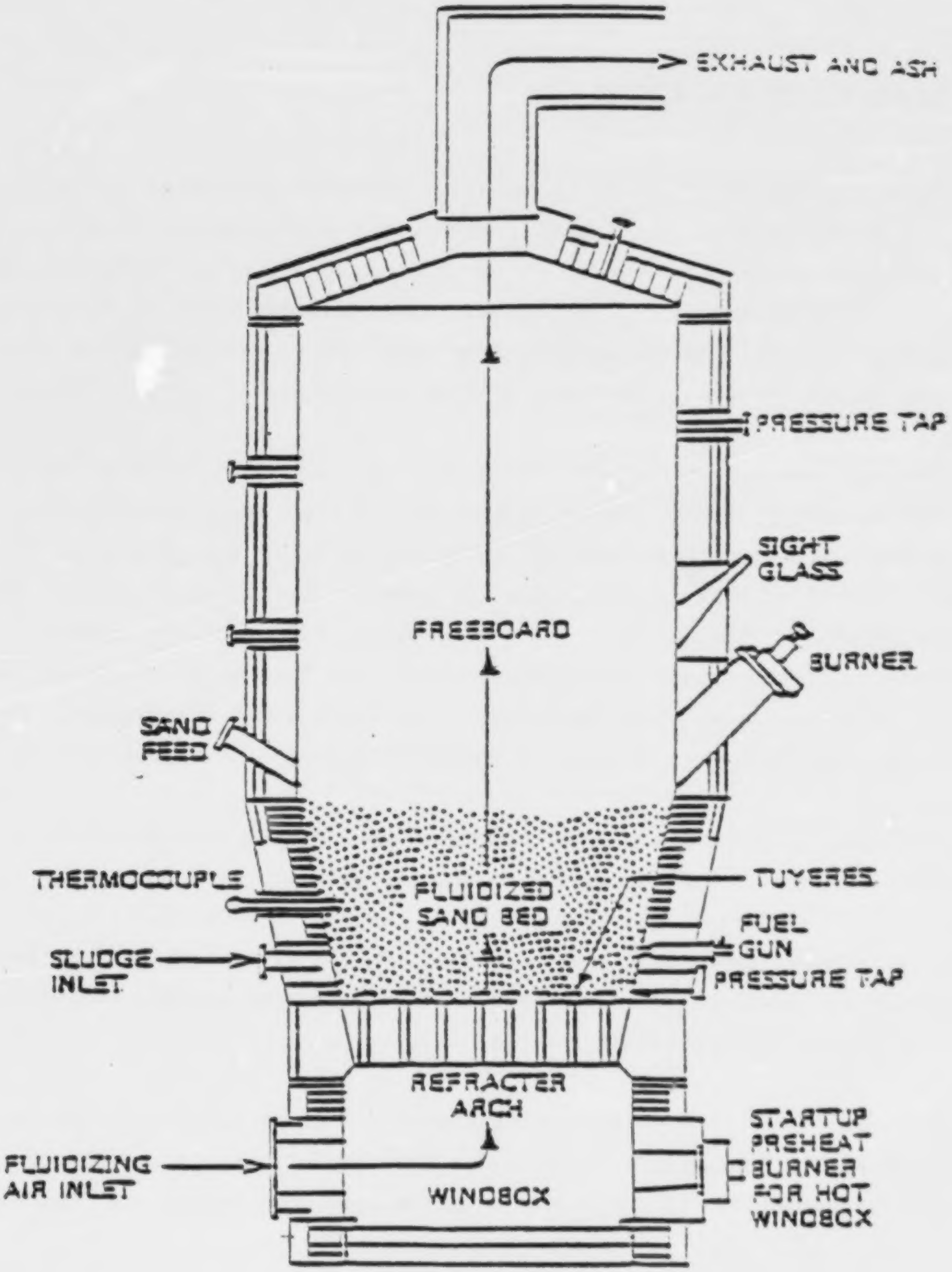
Fluidized-bed technology has been applied to a wide range of industrial processes since its initial development as a method for recovering catalysts in the oil refining industry. Coal drying and calcining operations in the phosphate industry are two other examples of industrial applications of FBI. The first fluidized-bed reactor designed specifically for incineration of sewage sludge was installed in 1961 in Lynwood, Washington.

2.1.2.1 Design Characteristics

Figure 2-2 depicts the cross-section of a fluidized-bed incinerator. Like multiple-hearth furnaces, FBIs are cylindrically shaped and vertically oriented. The outer shell is constructed of steel and is lined with refractory material. Tuyere nozzles are located at the base of the furnace within a refractory-lined arch.

Two general FBI configurations can be distinguished on the basis of how the fluidizing air is injected into the furnace. In the "hot windbox" design, the air is first passed through a heat exchanger where heat is recovered from the hot flue gases. Alternatively, in the "cold windbox" design, ambient air is injected directly into the furnace.

FIGURE 2.2. Cross-Section of a Fluidized-Bed Furnace


EXHAUST AND ASH
PRESSURE TAP
SIGHT GLASS
FREEBOARD
BURNER
SAND FEED
THERMOCOUPLE
FLUIDIZED SAND BED
TUYERES
FUEL GUN
SLUDGE INLET
PRESSURE TAP
REFRACTER ARCH
STARTUP PREHEAT BURNER FOR HOT WINDBOX
FLUIDIZING AIR INLET
WINDBOX

The physical dimensions of FBI units range from 6-25 ft in diameter. The corresponding range in the freeboard area is 30-525 ft^2. Fluidized-bed incinerators have sludge loading rates of between 30-60 wet $lb/hr/ft^2$ per bed. Burning capacities of FBI units range from 1/2 to 15 T/hr of wet sludge.

2.1.2.2 Operating Conditions

Partially dewatered sludge is fed into the lower portion of the furnace. The bed of hot sand and the incoming sludge are simultaneously fluidized by air injected through the tuyeres at pressures from 3-5 psig. Temperatures of 1,400-1,700°F are maintained in the bed. Gas residence times in the freeboard range from 2-5 sec. As the sludge burns, fine ash particles are carried out the top of the furnace. Some sand is also carried out in the air stream.

The ash from a fluidized-bed incinerator is typically collected wet from the wet scrubbing system. (Refer to Section 2.2.1 for more information on wet scrubbers.) The overall process of combustion of the sludge occurs in two zones. The first zone is within the bed itself. Here, water evaporation and pyrolysis of the organic materials occur almost simultaneously, as the temperature of the sludge is rapidly raised. The freeboard area is considered to be the second zone, which functions essentially as an afterburner. In this area, the remaining free carbon and combustible gases are burned.

In terms of combustion, fluidization of the sludge has a number of advantages. First, the turbulence in the bed facilitates the transfer of heat from the hot sand particles to the sludge. Second, nearly ideal mixing is achieved between the sludge and the combustion air as a result of the greatly increased and available surface areas. Third, the sand provides a relatively uniform source of heat within the bed.

The most noticeable impact of the improved burning atmosphere provided by a fluidized-bed incinerator, compared to the atmosphere provided by other furnace technologies, is the decrease in the amount of excess air that is required for complete combustion of sludge. Fluidized-bed sludge incinerators can achieve complete combustion with 20-50% excess air. This is about half the amount of excess air typically required for incinerating sewage sludge in multiple-hearth furnaces. As a result, FBI units generally have lower fuel requirements than MHF units.

The most critical operating variable of FBI units is the rate at which the sludge feeds into the incinerator. The upper limit of the rate of heat transfer that can be achieved for a given quantity of sand is based on whether the rate of sludge feed exceeds the burning capacity of the sand bed. If the burning capacity is exceeded, combustion will not be complete. Similarly, either a rapid increase in the overall furnace load or in the total moisture content of the sludge will coagulate the sludge into heavy masses, eliminate the fluidized nature of the bed, and halt combustion. For the same reasons, it is also important to ensure that an adequate residence time is available for the sludge to burn completely.

Due to their excellent mixing characteristics as well as their short residence times, however, fluidized-bed sludge incinerators are less vulnerable than MHFs to fluctuations in the rate of sludge feed and total moisture input into the furnace. Moreover, any disruption of combustion will occur almost immediately and can be more easily detected and corrected by the furnace operators.

2.1.3 Electric Furnaces

The electric infrared furnace represents a relatively new technological approach to sludge incineration. The first such unit was put into operation in Richardson, Texas, in 1975. Since that time, a number of installations have been constructed and others are in various stages of design.

2.1.3.1 Design Characteristics

Electric furnaces are horizontally oriented and consist of insulated enclosures through which sludge is transported on a continuous woven wire mesh conveyor belt (see Figure 2-3). The belt is made of steel alloy and can withstand the 1,700°F temperatures encountered in the furnaces.

The refractory is not brick, but ceramic felt, does not have a high capacity for holding heat. Therefore, the furnace can be started from a cold condition relatively quickly.

2.1.3.2 Operating Conditions

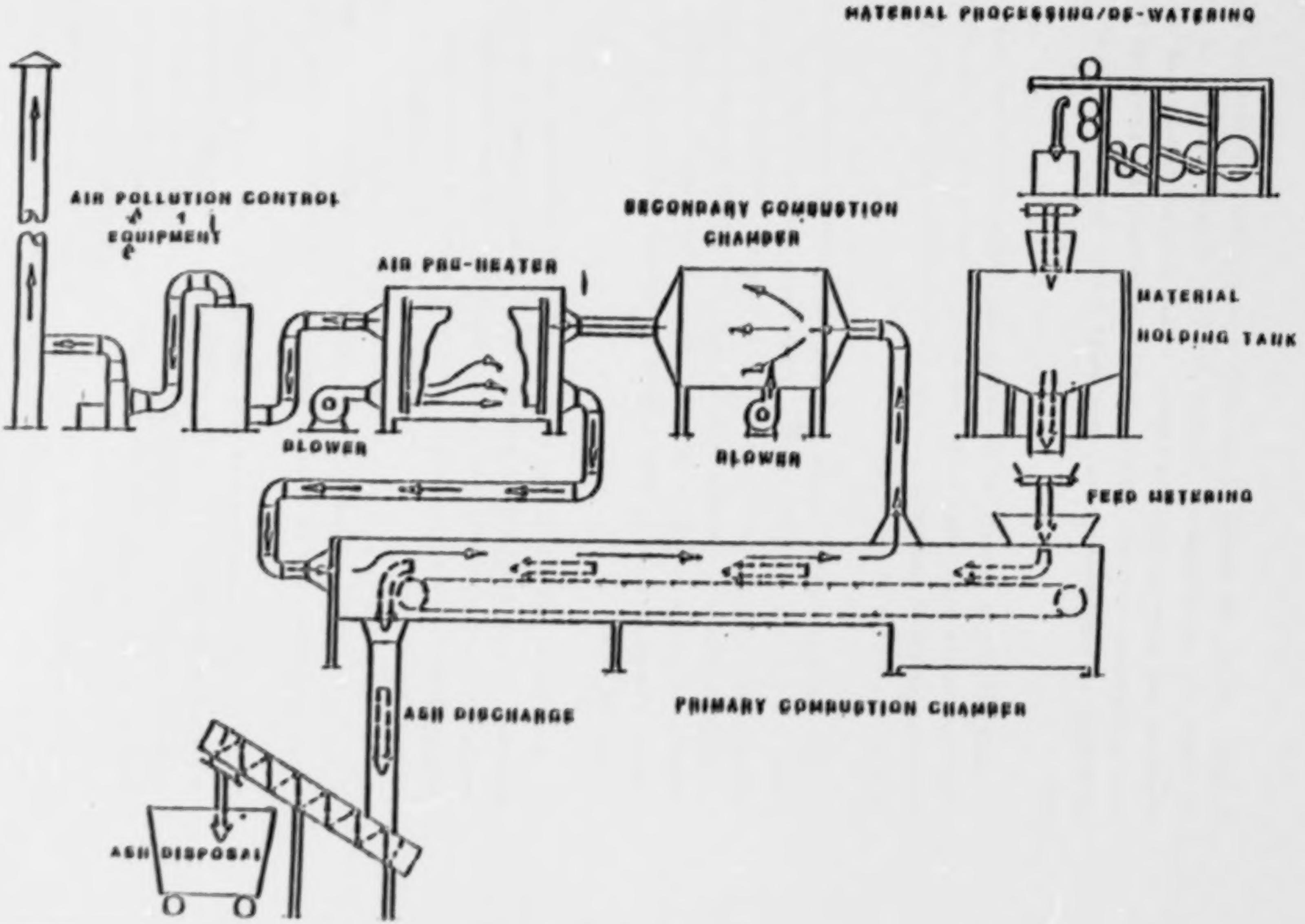
In electric furnaces, sewage sludge is fed into the unit through a feed hopper, dropped onto the conveyor belt, and leveled using an internal roller into a layer approximately 1 in thick, spanning the width of the belt. The sludge layer then moves under infrared heating elements, which provide any required supplementary energy needed to sustain the drying and incineration processes. The resulting ash is discharged from the end of the furnace into the ash-handling system.

Combustion air is introduced at the discharge end of the belt and is often preheated with an external recuperating exhaust heat exchanger. The air also picks up heat from the hot burning sludge as the sludge and air travel counter-current to each other.

Because the primary heat transfer mechanism used in the infrared furnace is radiant transfer, satisfactory combustion rates can be achieved without rabbling or plowing the sludge layer. Thus, compared to MHFs and FBIs, fly ash generation is minimized in electric furnaces and particulate emissions are more easily controlled.

Complete combustion can be achieved in the infrared furnace with excess air levels as low as 10-20%. This process efficiency is attributed to several

FIGURE 2-3. Process Flow Diagram: Infrared Incinerator System


MATERIAL PROCESSING/DE-WATERING
AIR POLLUTION CONTROL EQUIPMENT
SECONDARY COMBUSTION CHAMBER
AIR PRE-HEATER
MATERIAL HOLDING TANK
BLOWER
BLOWER
FEED METERING
ASH DISCHARGE
PRIMARY COMBUSTION CHAMBER
ASH DISPOSAL

factors. First, the design of the furnace is such that uncontrolled sources of excess air are eliminated. Second, the flow of combustion air is closely regulated and directed down the channel formed between the belt and the heating elements overhead. Third, no gaseous products are generated by the combustion of supplementary fuel that would dilute the supply of combustion air.

This ability to operate at low excess air levels contributes to a further reduction in the size, complexity, and energy requirements of the exhaust gas scrubbing equipment used with electric infrared furnaces. Ash from infrared furnaces is typically discharged as a dry solid.

The electric furnace system is divided into several temperature control zones for the incineration process. These zones are maintained at pre-determined temperatures by closed loop control. Temperatures are sensed by thermocouples and compared with the set point. Then the input power to the infrared heating elements is adjusted upward or downward, accordingly. Control temperatures range from 1,400°F in the drying zones to 1,700°F in the combustion zones.

The flow of air for sludge combustion is also controlled by a closed-loop process. The residual oxygen content in the exhaust stream is sensed continuously and compared with a set point value. In the event that a high-energy sludge is being processed, additional excess air may be used to limit exhaust temperatures to the 1,200-1,400°F range. The throughput of the system can be controlled by adjusting the speed of the internal conveyor belt. This adjustment is accomplished from the control panel and can also be used to adjust retention time in order to compensate for different sludge feeds.

To date, infrared furnaces have been used in smaller applications, where the greater operating flexibility of this type of furnace provides an advantage over traditionally larger multiple-hearth and fluidized-bed systems. Because of its ceramic fiber blanket insulation system, the infrared furnace is well suited for intermittent operation. This insulation system is not subject to the slow warm-up and cool-down thermal cycling requirements that are associated with the traditional types of solid refractory materials.

Start-up times of 1-1 1/2 hr are normal, and shutdown is accomplished by pressing a single "system stop" button. The furnace can be left unattended until it is restarted.

2.2 AIR POLLUTION CONTROL SYSTEMS

A variety of methods exist to destroy organic pollutants and remove particulates and their associated metals generated from sewage sludge incineration, e.g., wet scrubbers, dry and wet electrostatic precipitators, afterburners, and fabric filters. The estimated distribution of emission control systems applied to sludge incinerators is shown in Table 2-1, based on EPA's Office of Air Quality Planning and Standards survey (1987a). This section describes the types of air pollution control systems available for sludge incineration, focusing on the controls most widely used.

2.2.1 Wet Scrubbers

Historically, wet scrubbers have been the predominant air pollution control system used by POTWs; in addition, all sludge incinerators in the United States use wet scrubber systems. One reason for the widespread use of wet scrubbers is that sewage treatment effluent provides a relatively inexpensive source of scrubber water. Also, a system for treating the scrubber effluent is readily available in that scrubber water can be fed into the head of the treatment plant for solids removal. Another reason for the popularity of wet scrubbers is that they have a long history of success in meeting pollution control standards for particulate matter, as the systems have been designed to meet Federal and State requirements.

Wet scrubbers include venturi scrubbers, spray scrubbers or spray towers, and cyclone separators. As indicated in Table 2-1, a wide variety of wet scrubber controls are in use, ranging from low-pressure-drop spray towers and wet cyclones, where the pressure drops from 4-9 inch water gauge (WG), to

TABLE 2-1. Air Pollution Control Systems by Furnace Type, from Telephone Survey Database

	Multiple-Hearth	Fluidized-Bed	Electric Furnace	Coincineration
Undefined wet scrubber system	60	6		
Venturi/impingers	51	3	2	
Venturi/pack tower		2		
Impingers	36	3		
Wet cyclone	17	1		
Venturi	23	6	3	3
Wet cyclone/ impinger	1			
Spray chamber	1	2		
Dry electrostatic precipitators (ESPs)				4
Unknown	3			
Total 227 incinerators	192	23	5	7

higher-pressure-drop venturi scrubbers and venturi/ impingement-tray scrubbers, with pressure drops from 12-40 inch WG.

2.2.1.1 Venturi/Impingement-Tray Scrubbers

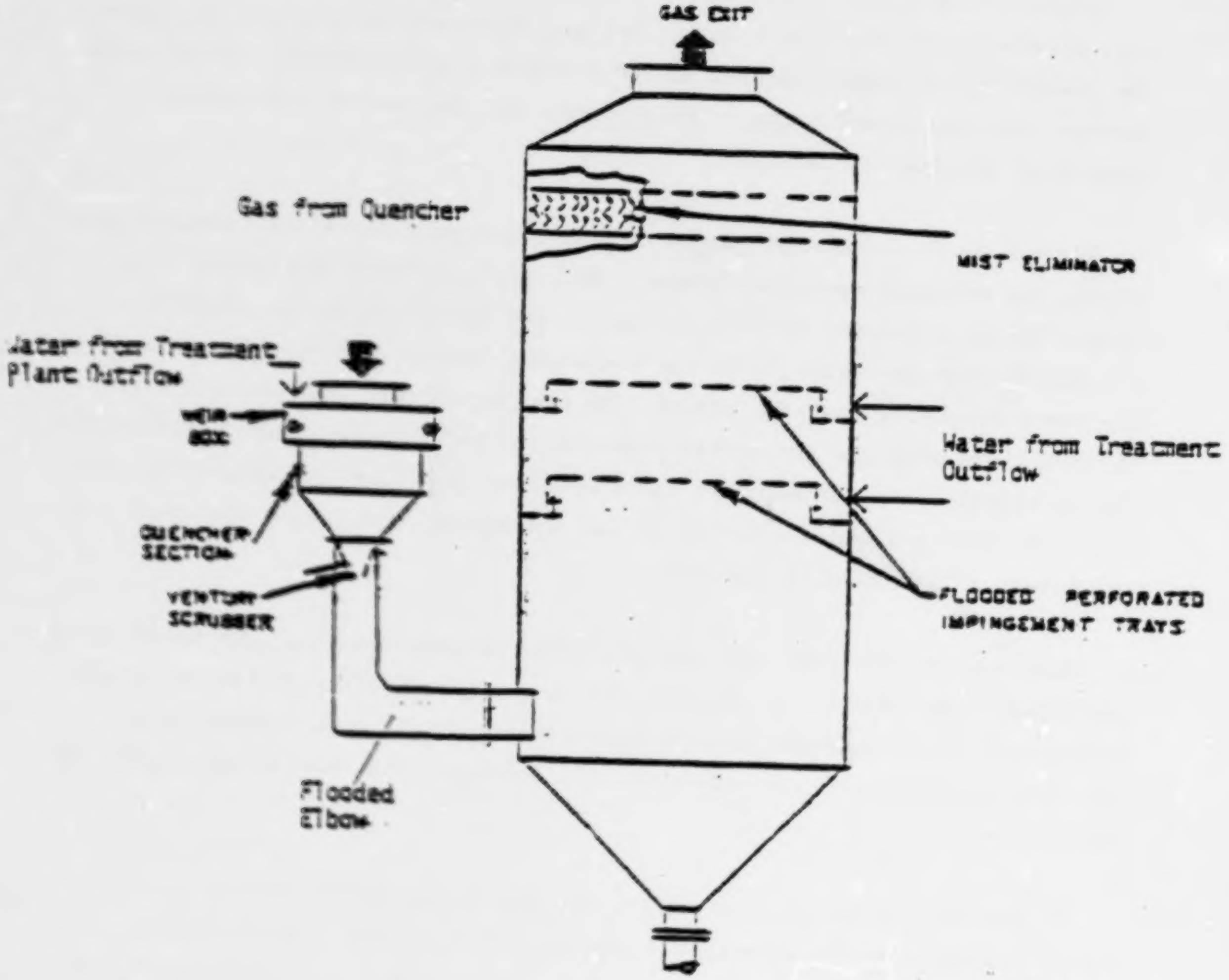
Figure 2-4 presents a simplified diagram of a typical venturi/impingement-tray scrubber. As the figure shows, hot gas exits the incinerator and enters the precooling or quench section of the scrubber. Spray nozzles in the quench section cool the incoming gas. The quenched gas then enters the venturi section of the control device.

Venturi water is usually pumped into an inlet weir above the quencher and enters the scrubber above the throat. This process floods the throat completely to eliminate build-up of solids and reduce abrasion. Turbulence created by high gas velocity in the converging throat section deflects some of the water traveling down the throat into the gas stream. Particulate matter carried along with the gas stream physically impacts these water particles and the water wall. As the scrubber water and flue gas leave the venturi section, they pass into a flooded elbow where the decreasing velocity of the water and gas stream allows them to separate.

Most venturi sections come equipped with variable throats. By restricting the throat area within the venturi, the linear gas velocity is increased and, subsequently, the pressure drop is also increased. Up to a certain point, increasing the venturi pressure drop also increases the removal efficiency of the system.

At the base of the flooded elbow, the gas stream passes through a connecting duct to the base of the impingement-tray tower, which usually contains from one to four trays. The gas stream enters the tower and passes upward through the perforated impingement trays, a movement that reduces the gas velocity further. Water from the treatment outflow usually enters the trays from inlet ports on opposite sides and flows across the tray. As gas passes through each perforation in the tray, it creates a jet that bubbles up

FIGURE 2-4. Cross-Section of a Venturi/Impingement-Tray Scrubber


GAS EXIT
Gas from Quencher
MIST ELIMINATOR
Water from Treatment Plant Outflow
WEIR BOX
QUENCHER SECTION
VENTURI SCRUBBER
Water from Treatment Outflow
FLOODED PERFORATED IMPINGEMENT TRAYS
Flooded Elbow

through the water and further entrains solid particles. A mist eliminator, located at the top of the tower, reduces the carryover of water droplets in the stack effluent gas.

2.2.1.2 Spray Scrubber (or Spray Tower)

The spray scrubber is a round or rectangular spray chamber into which water is introduced by spray nozzles. The three different configurations for spray chambers are concurrent flow, countercurrent flow, and cross flow. Spray scrubbers can collect both particulate matter and gaseous pollutants, but the collection efficiency for fine particles is low. Figure 2-5 shows a schematic of a simple countercurrent flow spray tower.

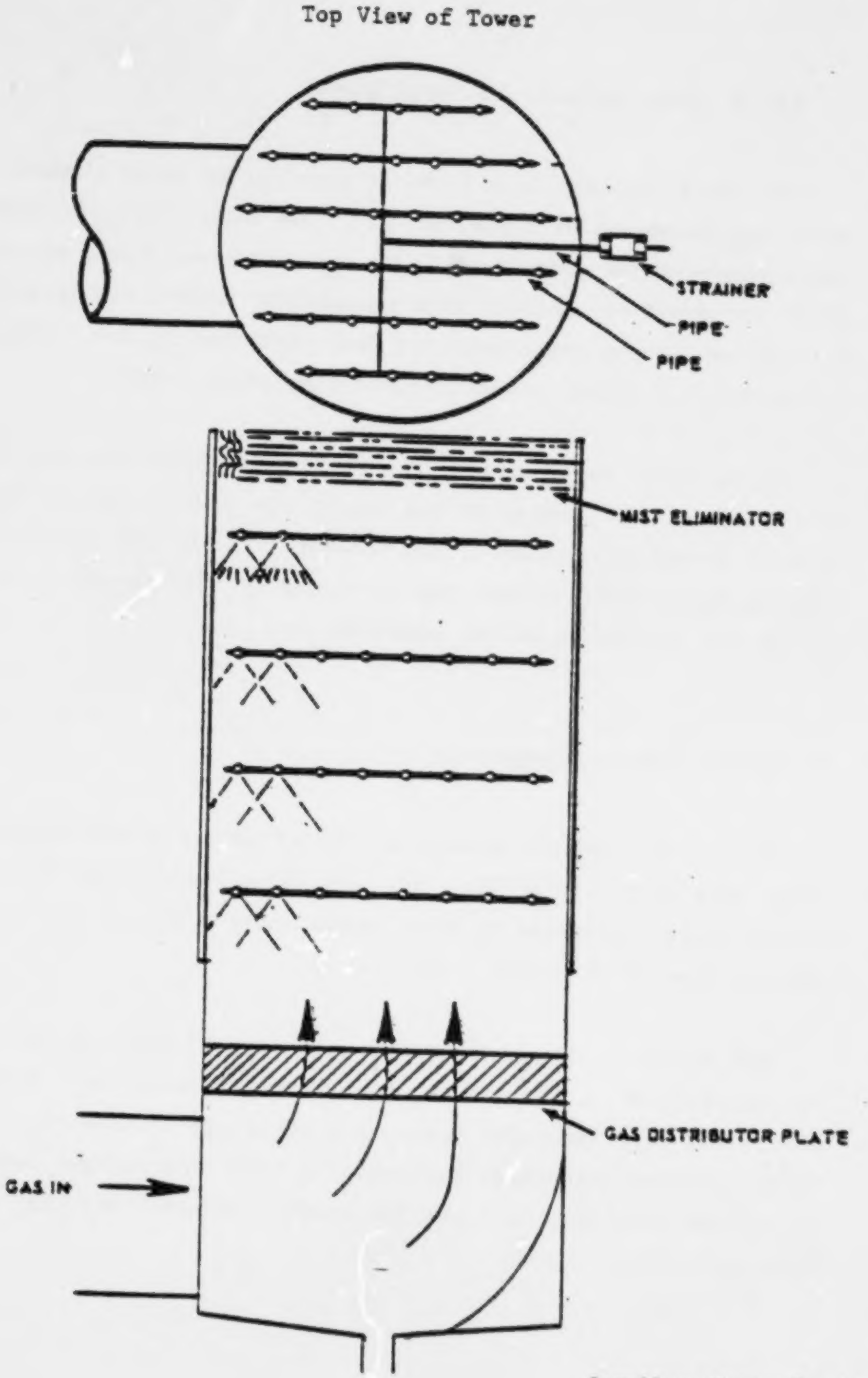
In the spray tower system, the fluid is sprayed into the enclosure by a series of nozzles located at the top of the chamber, while the gas-particulate mixture enters the bottom of the chamber. As the gas rises, it encounters the falling drops, which remove the particles by impingement. The scrubber water drains out the bottom of the scrubber.

2.2.1.3 Cyclone Separators

In general, cyclone separators are effective precollectors for removing large-size particulates from effluent gases, especially from fluidized-bed incinerators. Compared to more sophisticated devices, cyclone separators require less of a capital investment.

The degree of emission control exhibited by cyclone separators depends on the ash content of the wastes and incinerator capacity. In general, cyclones have a low efficiency for reducing visible and odor emissions because they have a limited capability for removing fumes and gaseous contaminants normally associated with visible smoke and odors. Cyclones are also not suitable for fine particulate control.

FIGURE 2.5. Typical Layout for Spray Tower


Top View of Tower
STRAINER
PIPE
PIPE
MIST ELIMINATOR
GAS DISTRIBUTOR PLATE
GAS IN
Scrubber Water Drain

There are basically two types of cyclone separators -- large-diameter, low-efficiency cyclones and small-diameter, high-efficiency multitube cyclones. Large cyclones have lower collection efficiencies, especially for particle sizes less than 30 u, and a low initial cost. They usually operate at a pressure drop of 1-3 in of water. The multitube cyclones are capable of eliminating over 90% of particles greater than 10 u. However, the cost of operating this type of system is higher and the pressure drop is usually 3-5 in of water. Historically, these systems are also more susceptible to plugging, erosion, and air leakage.

A conventional cyclone separator is show in Figure 2-6. It is customary to operate a number of cyclones in parallel in order to achieve practical gas volume.

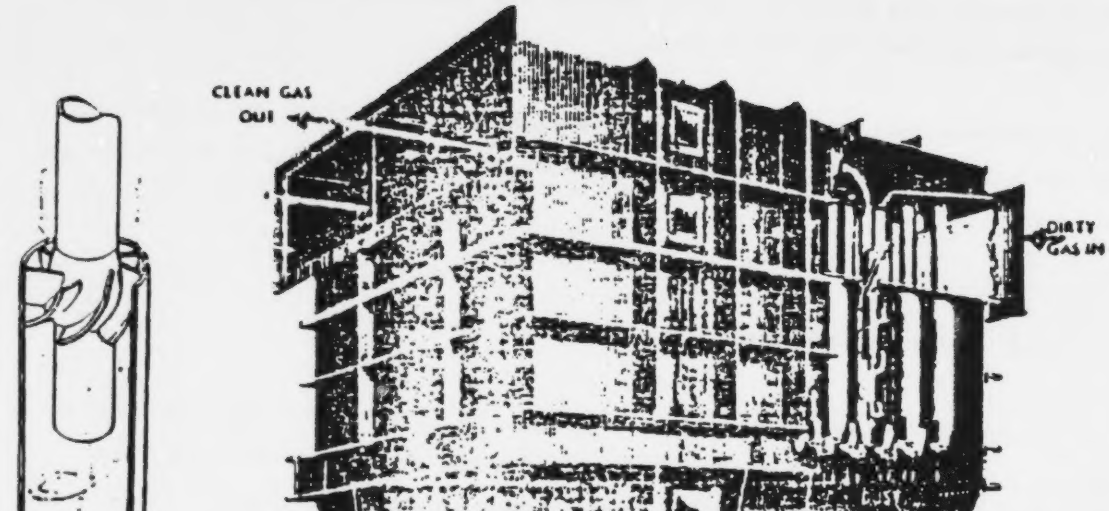
2.2.2 Electrostatic Precipitators (ESPs)

Electrostatic precipitation is a process by which particles suspended in a gas are electrically charged and separated from the gas stream under the action of an electric field. In this process, negatively charged gas ions are formed between emitting and collecting electrodes by applying a sufficiently high voltage to the emitting electrodes to produce a corona discharge. Suspended particulate matter becomes charged as a result of bombardment by the gaseous ions, which then migrate toward the grounded collecting plates due to electrostatic forces. The particle charge is neutralized at the collecting electrode, where subsequent removal of the particles occurs. A schematic of an ESP is shown in Figure 2-7.

2.2.2.1 Dry Electrostatic Precipitators

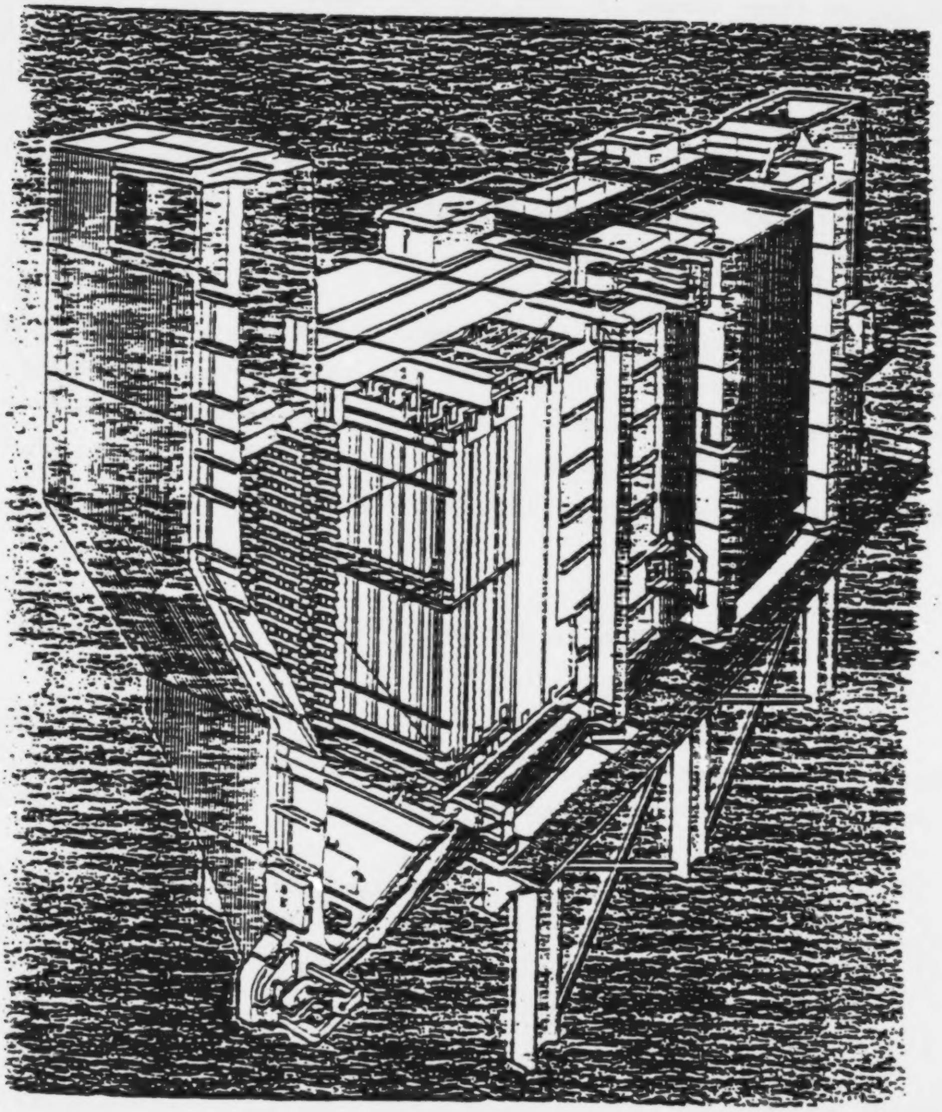
A majority of industrial ESPs used today are the dry single-stage, wire and plate type where charging and collection take place in the same section of the ESP. Two-stage ESPs, often called electrostatic filters, use separate sections for particle charging and collecting. Two-stage ESPs are not

FIGURE 2-6. Typical Cyclonic Dust Collector


CLEAN GAS OUT
DIRTY GAS IN

Enlarged cutaway shows inlet vanes, collecting cell and discharge tube.

FIGURE 2-7. Schematic of an Electrostatic Precipitator



generally employed for controlling particulate emissions from combustion sources. In dry ESPs, removal of particles occur by periodic tapping of the collection rates.

Compared to wet scrubbers, dry ESPs generally provide higher removal efficiencies for particles smaller than 1 u in diameter. Also pressure and temperature drops across dry ESPs are very small compared to those of wet scrubbers. The pressure drop across an ESP is typically below 1.00 in WG (0.25 kPa), whereas wet scrubbers often operate with pressure drops of up to 60 in WG (15 kPa). ESPs can generally handle a maximum temperature of 370°C and often placed downstream of waste heat boilers, where gas temperatures of 250-370°C are encountered. The collection plates on an ESP typically have a static voltage of 30 kV-75kV.

Electrostatic precipitators have been widely used with utility boilers and municipal and industrial incinerators. In some European facilities, ESPs are used with sludge incinerators. Dry ESPs are not capable of removing gases; therefore, if facilities burning sludge use dry ESPs, they must also employ another method of vapor control to remove gases.

2.2.2.2 Wet Electrostatic Precipitators (WEPs)

The wet electrostatic precipitator is a variation of the dry electrostatic precipitator design and is technically a wet scrubber system. The two major added features in a WEP system are:

- A preconditioning step in which inlet sprays in the entry section are used for cooling, gas absorption, and removal of coarse particles
- A wetted collection surface where liquid is used to continuously flush away collected materials

Particle collection is achieved by, first, introducing evenly distributed liquid droplets to the gas stream through sprays located above the electrostatic field sections. This action uniformly covers the particles with water, which makes the particles the same size and facilitates the induction of a charge on the particles. After the particles are charged, they migrate to the charged surfaces. To control the carryover of liquid droplets and mists to the stack plume, the last section of the WEP often operates without sprays and contains baffles to collect the mist.

Because of the uniformity of the WEP particles, the operation of the WEP is not influenced by the resistivity of the particles. Further, since the internal components are continuously being washed with liquid, buildup of sticky particles is controlled and there is some capacity for removal of gaseous pollutants.

In general, applications of the WEP fall into two areas -- removal of fine particles and removal of condensed organic fumes. Outlet particulate concentrations are typically in the 2-24 mg/m^3 range.

Wet electrostatic precipitators are used with metallurgic processes, acid mist collection, coke oven gas purification and other processes where wet conditions prevail or are desired. WEPs are not currently used with sludge incineration in the United States; but, due to the wet conditions that exist during sludge incineration, WEPs are being evaluated for future use.

2.2.3 Fabric Filters

Fabric filters have been used very successfully in many applications in which very high particle control efficiencies are achieved. To date, however, fabric filters have not been operated on a full-scale sludge incinerator in the United States. Only one incineration plant in the United States, in California, is equipped with fabric filters, and it was in the start-up phase in early 1988.

Fabric filters have not been applied to incinerator flue gas because acid gases attack the fabric, "sticky" particles bind the fabric; and unstable combustion and carryover of sparks into the flue cause baghouse fires. Electrostatic precipitators and wet scrubbers have been somewhat more tolerant of these problems and have generally been used instead of fabric filters.

Technologies are now available for fabric filters, however, that address these problems successfully, such as upstream scrubbing of acid gases and sorbent accumulation on fabric materials. Thus fabric filters are becoming a more attractive choice for particulate control, as well as for control of other pollutants.

Fabric filters combined with either a wet-dry or dry scrubbing system have demonstrated very high metals collection efficiencies when installed on municipal solid waste (MSW) combustors. This type of dry scrubber-fabric filter system is also being successfully used on a number of hazardous waste incinerators in Europe and the United States. These systems can probably be applied to sewage sludge incinerators to attain very high (99+%) metals removal efficiencies if needed to reduce incinerator metals emissions to acceptable risk levels. Currently, a fluidized-bed incinerator system with a dry scrubber-baghouse system is being built in the United States.

Fabric Filter Operation Mechanisms

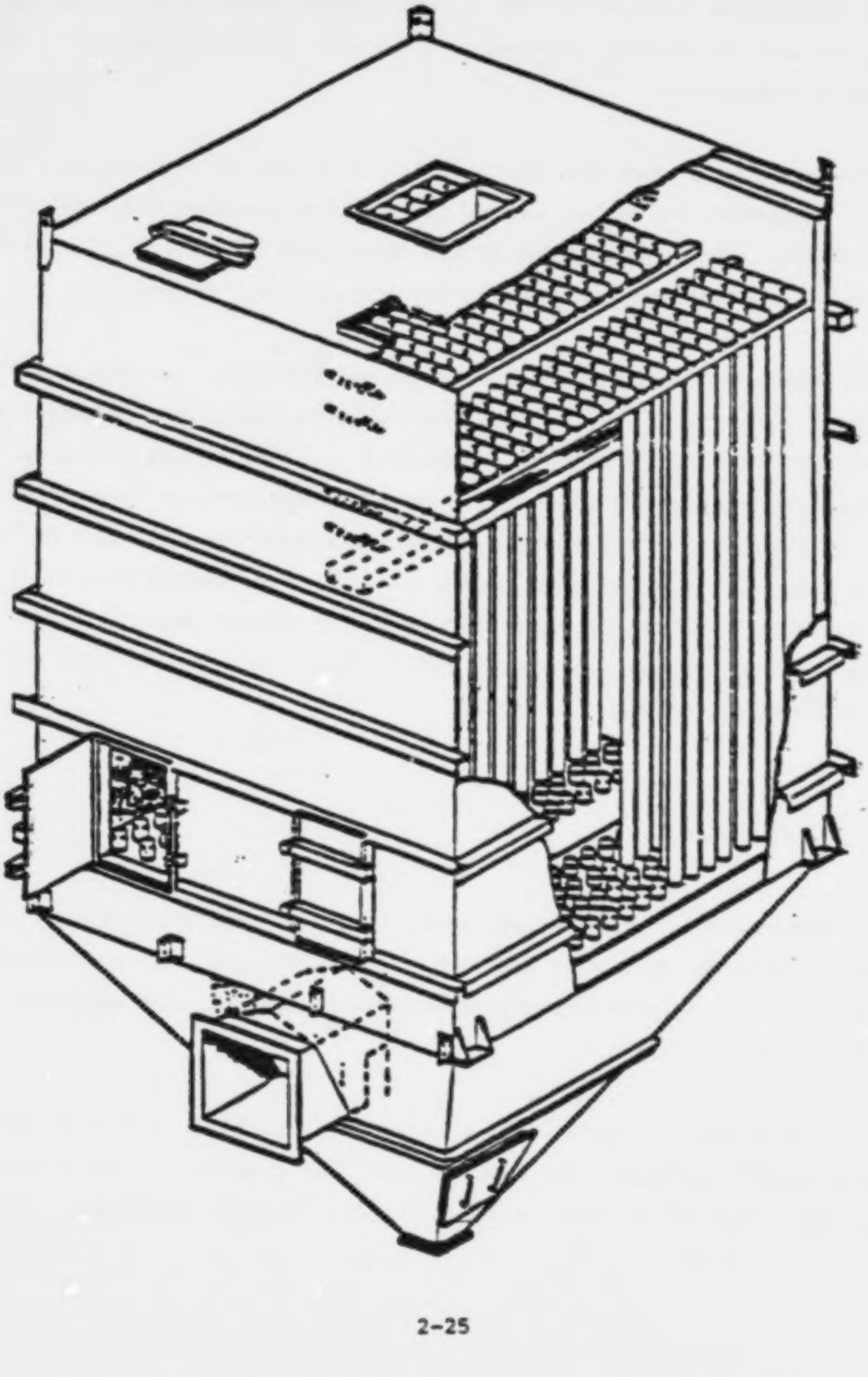
Figure 2-8 illustrates a typical reverse air fabric filter.

The five basic mechanisms for particulate collection in fabric filters are:

- Inertial impaction
- Brownian diffusion
- Direct interception
- Electrostatic attraction
- Gravitational settling

Inertial impaction is the dominant collection mechanism within the dust cake. The forward motion of the particles results in their impact on fibers or on already-deposited particles. Although impaction increases with higher gas velocities, these high velocities reduce the effectiveness of Brownian

FIGURE 2-8. Example of a Large Fabric Filter



diffusion. Increasing the fabric and dust cake porosity using a less dense fabric or more frequent cleaning also reduces diffusional deposition.

Except at low gas velocities, gravity settling of particles as a method of collection is usually assumed to be negligible. Electrostatic forces may affect collection because of the difference in electrical charge between the particles and the filter; however, the impact on commercial-scale equipment is not fully understood.

Sieving occurs when the particle is too large to pass through the fabric matrix. However, it is not one of the major mechanisms for collecting particulates. The combination of all these particle collection mechanisms results in high-efficiency removal for all particle sizes.

Moisture content and acid dew point are important gas composition factors. Operating a fabric filter at close to the acid dew points introduces substantial risk of corrosion, especially in localized spots close to hatches, in dead air pockets. in hoppers, or in areas adjacent to heat sinks, such as external supports. Allowing the operating temperature to drop below the water and/or acid dew point, either during startup or at normal operation, will usually cause blinding of the bags. Acids or alkali materials can also weaken the fabric and shorten its useful life. Trace components, such as fluorine, also can attack certain fabrics.

2.2.4 Afterburners

Afterburners are simple combustors used to destroy by oxidation the organic compounds that were not destroyed in the primary incinerator chamber. The three types of afterburners described in this section are direct-flame, thermal, and catalytic.

Direct-flame and thermal afterburners are similar, but they destroy organic vapors through different methods. In a direct-flame afterburner, a high percentage of the vapors pass directly through the flame. In a thermal unit, the vapors remain in a high-temperature, oxidizing atmosphere long enough for oxidation reactions to take place. Catalytic devices incorporate a catalytic surface to accelerate the oxidation reactions.

Both gaseous and liquid fuels are used to fire afterburners. Gaseous fuels permit firing in multiple jet, or distributed burners which exposes more matter to the fuel and results in more effective burnout of the organics. Oil firing, on the other hand, has the disadvantage of producing sulfur oxides (from sulfur in oil) and, usually, higher nitrogen oxide emissions than gaseous fuels.

2.2.4.1 Direct-flame Afterburners

Because direct-flame afterburners require significant amounts of fuel to operate, fuel costs are high. To improve the economic efficiency of direct-flame afterburners, these units are often used with a heat recovery system. Heat recovery is accomplished by generating process steam in a waste heat boiler, which recovers most of the energy produced in the combustion process. Another way to reduce fuel use in direct-flame afterburners is to use a recuperator or heat exchange system, which heats the incoming gas stream with the high-temperature exit gas.

2.2.4.2 Thermal Afterburners

To ensure destruction of organic vapors, thermal afterburners expose the vapors to a high-temperature, oxidizing atmosphere. Temperatures ranging from 650-1,300°C are generally required for successful operation of these devices. Usually, organic compound levels can be satisfactorily reduced at temperatures of 760°C, but higher temperatures may be required to oxidize carbon monoxide. The following temperatures are often used as oxidation guidelines:

- Hydrocarbons -- 500-650°C (930-1,200°F)
- Carbon monoxide -- 650-800°C (1,200-1,472°F)

The residence time in most operating afterburner systems is dictated primarily by the chemical kinetic properties of the gases. To ensure good mixing, afterburners are operated at high-velocity gas flows. Superficial gas velocities in afterburners range from 25-50 ft/sec. Depending on the type of pollutant in the gas stream, residence times ranging from 0.2-6.0 sec are required for complete combustion.

2.2.4.3 Catalytic Afterburners

Catalytic afterburners are used to destroy gaseous wastes containing low concentrations of combustible materials and air. Usually, noble metals such as platinum and palladium are the catalytic agents. (A catalyst is defined as a material that promotes a chemical reaction without taking part in it. The catalyst does not change nor is it used up. However, it is subject to contamination and loss of its effectiveness.)

Residence time for catalytic oxidation is typically about 1 sec. Because the combustion reaction occurs on the surface of the catalyst, the catalyst must be supported in the hot waste gas stream so that it exposes its greatest surface area to the waste gas. The reaction produces the non-toxic effluent gases of carbon dioxide, nitrogen, and water vapor. Most of the combustion occurs during the gas flow through the catalyst bed, which operates at maximum temperatures of 810-870°C.

The catalytic incinerator can carry out combustion of gaseous wastes at relatively low temperatures while achieving high destruction efficiencies. Another major advantage is that the need for fuel is eliminated.

Generally, catalytic afterburners are considered when waste combustion gases contain hydrocarbon levels that are less than 25% of the lower explosive limit. When the waste gas contains a heating value sufficient to cause concern about catalyst burnout, the gas may be diluted by atmospheric air to ensure an operating temperature within the temperature limits of the catalyst.

2.3 ASH MANAGEMENT

Ash from the incineration of municipal wastewater treatment sludge is typically an inert solid that may be either wet or dry. It is usually disposed of in landfills or lagoons. Some plants may dispose of incinerator ash as a filler in construction materials such as concrete, asphalting, blocks.

The disposal of ash falls under the jurisdiction of the Resource Conservation and Recovery Act (RCRA) (40 CFR 257, 258, and 261-268) and is not covered in the sewage sludge regulations. Any or all of the current or anticipated disposal or reuse methods may be environmentally protective, as long as the release of either metals or any residual organics does not create a potential health hazard, according to RCRA.

SECTION THREE

DEVELOPMENT OF A DATABASE FOR SLUDGE INCINERATORS

Two databases were developed for sludge incineration to provide information on the distribution and use of various incinerator technologies. The data were also used as input to the air dispersion models, the risk methodology, and the numeric limit calculations. The databases are as follows:

- An incinerator population database, which identifies the parameters needed to perform risk-based calculations for individual sites and the aggregate national total
- An emissions control data base, which provides data for predicting how much of a pollutant in incinerated sludge emissions will be discharged into the environment

3.1 INCINERATOR POPULATION DATABASE

EPA's Office of Air Quality, Planning and Standards conducted an extensive phone survey to obtain and update detailed information on sewage sludge incinerator facilities in the United States (EPA, 1986a). The work was initially undertaken to develop a database for possible regulation of chromium emissions from sewage sludge incinerators as a National Emission Standard Hazardous Air Pollutant (NESHAP), as addressed in the Clean Air Act (CAA).

The survey identifies 127 sites and is estimated to contain information on greater than 80% of all operational sewage sludge incinerators in the United States. Specific information was collected on location, type and numbers of incinerators, capacities, operating cycles, building dimensions, scrubber type, and stack parameters. The complete database is presented in Appendix A.

An Agency analysis of the database revealed the following information:

- 127 sites have a total of 227 incinerators in the following categories:
  - -- 192 multiple-hearths
  - -- 23 fluidized-beds
  - -- 5 electric (infrared) furnaces
  - -- 7 coincinerators with solid waste facilities
- Total capacity of all of the incinerators is 8,175 dry metric tons (or megagrams, Mg) of sludge per day. The average capacity is 35 dry Mg/day. The distribution of capacity for the 127 sites is shown in Figure 3-1.
- Average stack height was 19 m. The distribution of stack heights is presented in Figure 3-2.
- Stack exit gas velocities ranged from 1-32 m/sec. The distribution of stack velocities is shown in Figure 3-3.
- Distribution of air pollution control systems by incinerator type is shown in Table 2-1.
- The average operating week is five days.

This database was specifically used in the following ways during the development of the proposed regulation:

- To supply information on the representative plants that were used to evaluate the risks of the proposed rule (see Section 5 for more information on the risk analysis)
- To develop the air dispersion factors used in the sensitivity analysis of the air dispersion models (see Section 4 for more details on the air dispersion modeling process)
- To develop the worst-case dispersion factors used in the simplified air model for demonstrating compliance with the RSDs associated with metal pollutants (see Section 6 for more information on the metal RSDs)

3.2 AIR EMISSIONS CONTROL EFFICIENCY DATABASE

A major factor in determining the health impact of sewage sludge incinerators is the overall control efficiency of the incinerator furnaces and air pollution control systems. The control efficiency is based on the

FIGURE 3-1. Distribution of Capacity for 127 Sludge Incinerator Sites

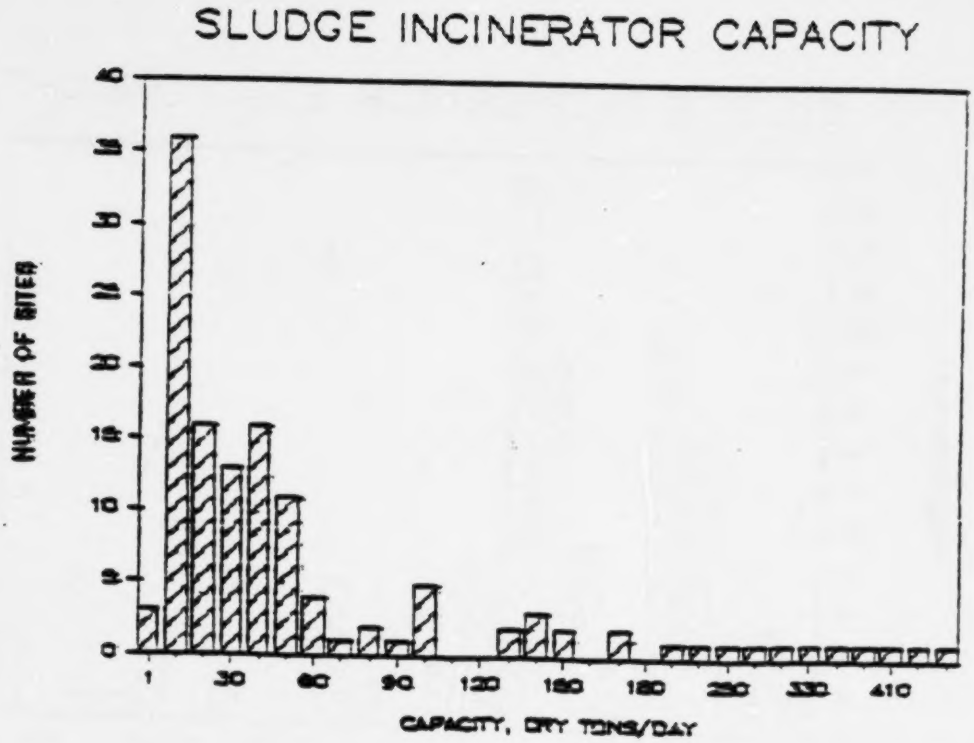


FIGURE 3-2. Distribution of Stack Heights for Sludge Incinerators

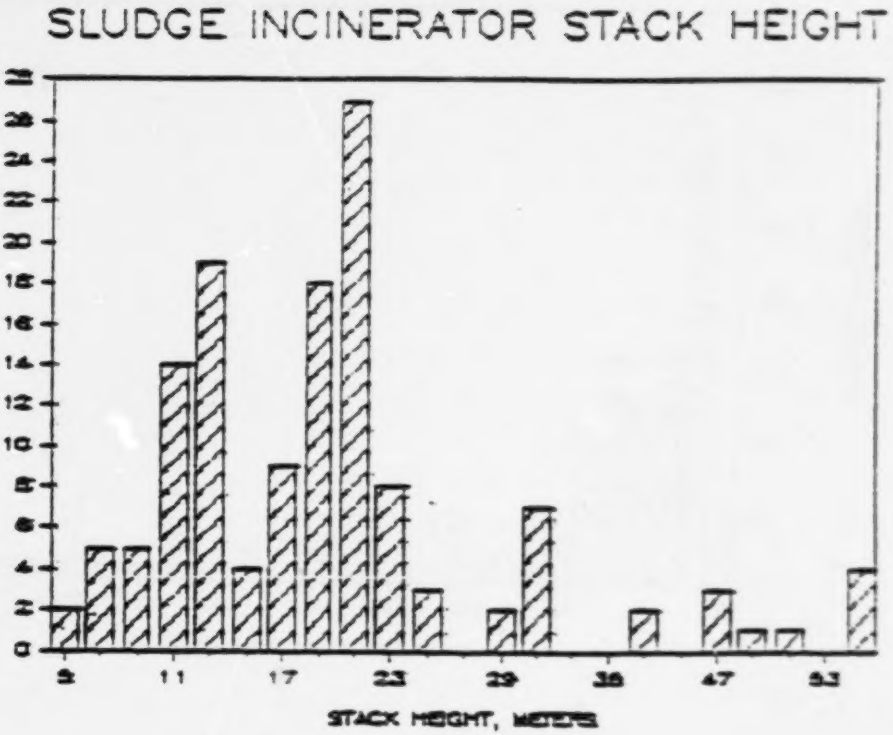
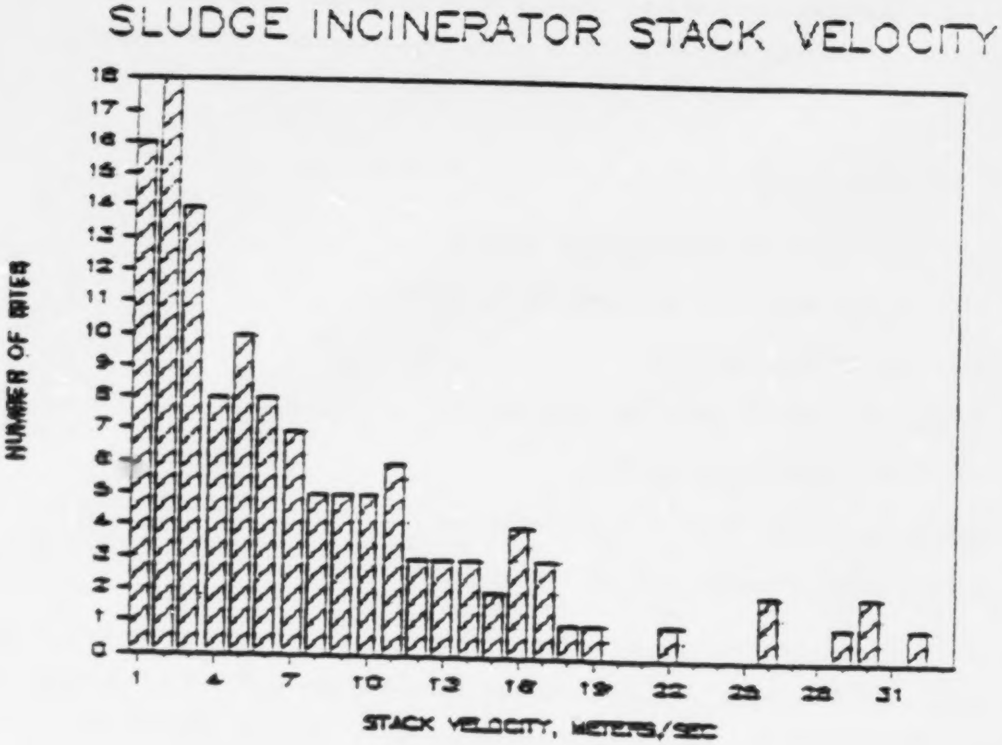


FIGURE 3-3. Distribution of Stack Exit Gas Velocities for Sludge Incinerators



quantity of pollutant in the sludge that is being fed into an incinerator in relation to the quantity of pollutants emitted from the incinerator stack. Control efficiencies were specificially used to determine the allowable emission limits for metals.

3.2.1 Development and Scope of the Database

Information from several independent, overlapping, and comprehensive literature searches was used to compile this database. Standard operating conditions for multiple-hearth and fluidized-bed sewage sludge incinerators were compiled from 16 studies, which are listed in Table 3-1.

The following parameters were reviewed in each study:

- Type and number of incinerators sampled
- Type of scrubber used for each incinerator
- Sampling method employed
- Number of samples taken per incinerator
- Elements chosen for analysis
- Operating condition of the incinerators
- Analysis and presentation of results

Due to differences in format and level of detail of the data provided in the reference documents, a subset of the database was created to analyze the control efficiencies. Data were omitted from this analysis based on:

- Duplication of field data. References 2 and 11 present different analyses of the same field data. Reference 11 contains more detailed data listings and was included in the database subset. The data obtained from Reference 2 were not included.
- Data omissions. An observation was included in the database only if both the pollutant feed and emission rates were reported. A result of "nondetectable" was considered to be a valid observation for constructing the database. For this reason, certain data observations in References 3, 5, 8, and 11 were not included.

TABLE 3-1. Literature Studies Reviewed for Air Emissions Control Database Development

1. White, M. and G. Beluzo. 1980. Performance tests and material balance for a fluidized-bed sludge incinerator. Prepared by GCA Corporation. Environmental Protection Agency.

2. Wall, H. and J. Farrell. 1979. Particulate emissions from municipal wastewater sludge incinerators. Paper presented at the Mid-Atlantic States Section Air Pollution Control Association Meeting, Newark, New Jersey. Cincinnati, OH: Municipal Environmental Research Laboratory.

3. Copeland, B.J. 1977. A study of heavy metal emissions from fluidized-bed incinerators. In: Proceedings of the 30th Industrial Waste Conference May 6-8, 1975, 78-79. Ann Arbor: Ann Arbor Science.

4. Greenberg, R.R., W.H. Zeller and G.E. Gordon. 1981. Atmospheric emissions of elements of particles from the parkway sewage sludge incinerator. Env. Sci. and Tech. 15(64).

5. Bennet, R.L., K.T. Knapp and D.L. Duke. 1984. Chemical and physical characterization of municipal sludge incinerator emissions. Report No. EPA 600/3-84-047. NTIS No. PB 84-169325. Research Triangle Park, NC: Environmental Sciences Research Laboratory.

6. EPA (U.S. Environmental Protection Agency). 1972. Sewage sludge incineration. Report No. EPA R-2-77-040.

7. Dewling, R.T., R.M. Manganelli and G.T. Baer. Fate and behavior of selected heavy metals in incinerated sludge. J. Wat. Pollut. Contr. Fed. 52(10):2552-2557.

8. Adams, R.C., L.E. Keller and E.V. Robb. 1985a. Particulate removal capability of a baghouse filter on the exhaust of a multiple-hearth furnace burning sewage sludge. Draft. Prepared by Radian Corporation for the Water Engineering Research Laboratory (WERL). EPA Contract No. 68-03-3148.

9. Adams, R.C., G. Bockol, J.A. Maddox and E.V. Robb. 1985b. Particulate removal evaluation of an electrostatic precipitator dust removal system installed on a multiple-hearth incinerator burning sewage sludge. Draft. Prepared by Radian Corporation for the Water Engineering Research Laboratory (WERL), Cincinnati, OH. EPA Contract No. 68-03-3148.

10. Klinger, W.A. 1986. Biological sludge incinerator air impacts study. Prepared by TRC Environmental Consultants. Arlington, VA: Arlington County Department of Public Works.

TABLE 3-1. (Continued)

11. Farrell, J.B. and H. Wall. 1981. Air pollution discharges from ten sewage sludge incinerators. Rev. No. 1, draft. Cincinnati, OH: Municipal Environmental Research Laboratory, Ultimate Disposal Section.

12. EPA (U.S. Environmental Protection Agency). 1986b. Method development and testing for chromium sewage sludge incinerator no. 13, Detroit Water and Sewer Department, Detroit, Michigan. Research Triangle Park, NC: Office of Air Quality and Planning Standards, Emission Measurement Branch.

13. Knisley, D.R., L.M. Lamb and H.M. Smith. 1988. Site 1 draft emission test report, sewage sludge test program. Prepared by Radian Corporation. EPA Contract No. 68-02-6999.

14. Knisley, D.R., K.W. Barnett and D.J. Holder. 1987. Site 2 draft emission test report, sewage sludge test program. Prepared by Radian Corporation. EPA Contract No. 68-02-6999.

15. Knisley, D.R., K.W. Barnett and D.J. Holder. 1987. Site 3 draft emission test report, sewage sludge test program. Prepared by Radian Corporation. EPA Contract No. 68-02-6999.

16. Knisley, D.R., K.W. Barnett and H.A. Palazzolo. 1988. Site 4 draft emission test report, sewage sludge test program. Prepared by Radian Corporation. EPA Contract No. 68-02-6999.

- Peculiarities in the method of data collection. Reference 6 was excluded from the database due to a lack of correspondence between the samples collected for a pollutant concentration analysis and those collected to determine the feed and emission rates.

After the elimination process, data from 27 incinerators were included in the database. Of the 27 incinerators, 18 were multiple-hearth incinerators and 9 were fluidized-beds. A list of the incinerators is shown in Table 3-2. The table also identifies the air pollution control system and furnace type used by each facility.

3.2.2 Compilation of the Database

The database contains information on sludge feed and particle emission rates, metal loading and emission rates, and scrubber efficiencies by incinerator. Because the studies differed in scope and purpose, the quantity of data varied with respect to the number of incinerators tested, the number of metals analyzed, the number of sample runs conducted, and whether scrubber efficiencies were measured.

After the data were compiled, they were converted to units appropriate for statistical analysis. The sludge feed rate was converted to a dry matter basis with units in kg/hr. The particulate emission rate was also converted to kg/hr. Metal feed and emission rates were converted to mg/hr. The compiled data were then reviewed to determine which information was suitable for inclusion as variables in the database. The data were then coded into a completed database program.

TABLE 3-2. Summary of Incinerator Information Evaluated for Emission Control Database

Study Ref. No.	Number & Type of Furnace	Number & Type of Scrubber	Evaluated Elements	Scrubber Efficiency	Test Method	Number of Samples per Furnace	Data Discrepancies
1	1 FBI	Venturi and tray	7	No	SASS and M5	3	
2	7 MHF 1 FBI	3 Impingement 4 Venturi and impingement 1 Wet cyclone	4	Yes	SASS	1	Data not used; duplicate of Study #1
3	3 FBI	2 Wet Venturi and packed tower 1 Venturi and impingement	8	No	M5	6	(a)
4	1 FBI	Venturi and packed tower	27	No	M5	5(b)	
5	3 MHF 1 FBI	1 Cyclone 3 Tray	25	Yes	M5	45-95(b)	(a)
6	2 MHF 1 FBI	2 Impingement 1 Inertial jet	15	No	Other	3 1	Data discounted
7	1 FBI	Impingement	7	No	M5	3	
8	MHF	Cyclone and Venturi and impingement	24	Yes	SASS	3	(a) (c)
9	MHF	Cyclone and Venturi and impingement	24	Yes	SASS	3	(c)
10	1 MHF	Wet scrubber	3	No	MM5	7	(a)
11	7 MHF 2 FBI	1 Cyclone 4 Venturi and impingement 4 Impingement	9	Yes	SASS	1	
12	1 MHF	Impingement	1	Yes	M5	4	
13	1 MHF	Impingement	-	No	Vost MM5	5	

TABLE 3-2 (continued)

Study Ref. No.	Number & Type of Furnace	Number & Type of Scrubber	Evaluated Elements	Scrubber Efficiency	Test Method	Number of Samples per Furnace	Data Discrepancies
14	1 MHF	Impingement		Yes	"	5	
15	1 FBI	Venturi		No	"	3	
16	1 MHF	Venturi Afterburner	y	Yes	"	9	

(a) Some observations not included due to data omissions.

(b) Analysis reported as aggregates.

(c) Studies #8 and #9 were conducted on the same incinerator, testing two different types of air pollution control systems. Refer to Table 3-1 for more information.

CEM - Continuous emissions monitoring
FBI - Fluidized-bed incinerator
M5 - EPA Method 5 for particulates
M12 - EPA Method 12 for metals
MHF - Multiple-hearth furnace
MM5 - Modified EPA Method 5 for particulates
SASS - Source Assessment Sampling System for particulates
VOST - Volatile organic sampling train

SECTION FOUR

DESCRIPTION OF THE AIR DISPERSION MODELS

In the proposed regulations, atmospheric models were used to develop air dispersion factors, which are major parameters used to determine the allowable sludge concentrations for metals and stack emission rates for THCs. Using specific risk levels and incinerator types, the models also estimated allowable ground-level concentrations at certain locations in the vicinity of the incinerator as part of the development of the reasonable worst-case scenario. Refer to Section 5 for information on the risk methodology and Section 6 for information on dispersion factors.

4.1 MODEL SELECTION

The dispersion models used to develop the sludge incinerator regulations were chosen due to the recommendations contained in the Guideline on Air Quality Models (EPA, 1986c). The models were selected according to their ability to predict various situations in urban or rural areas and simple or complex terrains, and their available options, such as their ability to predict building aerodynamic downwash. In addition to recommending specific models, the Guideline recommends the incinerator and meteorological data that are used in these models.

Three dispersion models were evaluated for this regulation and used during the risk assessment. They include the Industrial Source Complex Long Term (ISCLT) model, the LONGZ model, and the COMPLEX I model. ISCLT assesses rural or urban concentrations where the terrain elevations do not exceed the stack height. This model includes the effects of building aerodynamic downwash, which is most likely to be significant for many sludge incinerators with short stacks (see discussion below). LONGZ models surface concentrations in urban complex terrain, while COMPLEX I computes surface concentrations in rural complex terrain. LONGZ and COMPLEX I are most appropriate in situations where terrain elevations exceed stack height.

All three models require input data on incinerator stack height, exit diameter, gas flow, and gas temperature to estimate emission rates and plume rise. They also require data on meteorology and the specific location of the MEI. In the modeling, the location of the MEI is not specified beforehand, but is set at the location predicted by the model to have the highest long-term average concentration.

The meteorological data required to run the models must be in the form of joint frequency distributions of wind speed, wind direction, and atmospheric stability, sometimes referred to as "statistical wind summaries" or as Stability Array (STAR) data. These databases can be obtained from major commercial airports.

Before selecting a model, the model user must determine whether the incinerator is in an urban or rural environment and whether building downwash will be a factor. The Guideline describes the process of classifying a location as urban or rural, depending on how the land is used in more than 50% of the area within a 3-km radius of the incinerator.

The Building Downwash Factor

Most sewage sludge incinerators have short stacks that are not much higher than the buildings on which they are located. As a result, the incinerator plumes impact the buildings and are deflected onto the ground in the area surrounding the building. Because of this aerodynamic building downwash effect, the highest ground concentrations of pollutants are found close to the incinerator. Thus the selection of the model depends on the design of the sludge incinerator stack and building downwash must be considered when the model incinerator has a short stack.

4.2 MODEL DESCRIPTIONS

4.2.1 ISCLT Model

According to the Guideline, ISCLT is the only EPA-accepted atmospheric dispersion model that considers the effect of downwash in computing ground concentrations of pollutants that occur close to the incinerator. It is based on the assumption that a continuous emission will produce a Gaussian (bell-shaped) plume (EPA, 1986d). Building downwash is estimated using calculated specialized formulas (Huber, 1976; Huber and Snyder, 1976). Plume rise is predicted based on the temperature of the emission and the atmospheric stability of the site. Using wind profile exponents, the ISCLT model also computes the change in wind speed with height according to stability.

The ISCLT model is only intended to compute concentrations in simple terrain (terrain less than or equal to stack height). Consequently, when the MEI is located in complex terrain (terrain greater than stack height), LONGZ or COMPLEX I would be more appropriate for predicting ground concentrations.

4.2.2 LONGZ Model

LONGZ can be used in place of ISCLT when the dispersion of incinerator emissions in complex terrain is assessed for an urban area. LONGZ uses different plume rise equations than the ISCLT model. LONGZ also uses "Cramer dispersion coefficients" rather than the Pasquill-Gifford dispersion curves used in ISCLT (EPA, 1982). Another difference between LONGZ and ISCLT is that LONGZ uses vertical turbulence intensities to compute vertical plume dimensions and does not include the effects of aerodynamic building downwash.

4.2.3 COMPLEX I Model

When incinerator emissions are assessed in rural complex terrain, COMPLEX I can be used in place of ISCLT. COMPLEX I uses the steady-state Gaussian plume equation for each hour of a meteorological record in sequence (Chico, 1986). The hourly ground concentrations predicted by the model must be multiplied by the appropriate statistical wind summary frequency factor and then summed to obtain the annual mean concentration at each location. Like ISCLT, COMPLEX I uses Briggs plume rise equations and Pasquill-Gifford dispersion curves. COMPLEX I also employs the ISCLT approach of computing the change in wind speed with height according to stability using wind profile exponents.

4.3 MODEL COMPARISON TESTS

To compare the models, the Agency modeled ten existing sewage sludge incinerators with ISCLT and either LONGZ or COMPLEX I (EPA, 1987b). Maximum ground level concentrations were predicted. For the comparison, ISCLT was applied at complex terrain locations, with the terrain elevations set equal to stack height. Complex terrain locations were modeled using actual elevations with LONGZ for urban facilities and COMPLEX I for rural facilities. The comparisons indicated that ISCLT predicts the worst-case or highest ground level concentrations.

4.4 ISCLT SENSITIVITY ANALYSES

EPA conducted a sensitivity analysis of the ISCLT computer model to determine the feasibility of developing a simplified model that can predict compliance with the risk-specific doses, as discussed in Section 5 (EPA, 1987b). The sensitivity analyses were designed to evaluate how maximum allowable sludge concentrations vary during extreme ranges of the following parameters:

- Incinerator stack design, including stack height and emission temperatures
- Meteorologic conditions

- Location of the MEI, who by definition resides either wherever the maximum ground concentration was predicted to occur, or at 200, 500, and 1,000 meters (m) from the incinerator

To determine a reasonable worst-case situation for incineration design and meteorologic conditions, the Agency selected ten existing sewage sludge incinerators that were representative of the incinerator types, range of stack heights, feed rates, and meteorologic conditions that are present in the United States. The results of modeling these sites are presented in Appendix B.

4.4.1 First Sensitivity Analysis

The first sensitivity analysis evaluated the effect of meteorology on the reasonable worst-case sludge concentrations. In every EPA region, the Agency's regional meteorologists selected weather stations that best represented the local meteorology. The reasonable worst-case facility was modeled using joint frequency distributions of wind speed, wind direction, and atmospheric stability from 18 different weather stations across the country.

The results of these analyses indicated that changes in meteorology did not cause order of magnitude differences in the maximum allowable sludge concentrations. The maximum increase in allowable sludge concentrations based on meteorology was a factor of 1.4, when the MEI was located at the maximum ground concentration point; a factor of 2.1, when the MEI was located at 200 m; a factor of 2.4, when the MEI was located at 500 m; and a factor of 2.5, when the MEI was located at 1,000 m.

4.4.2 Second Sensitivity Analysis

The second sensitivity analysis generated a regression relationship between dispersion factor and stack height to evaluate the effect of stack height on the reasonable worst-case sludge concentrations. For these analyses, the meteorology and building dimensions for the reasonable worst-case facility were held constant while stack height was varied. The full range of incinerator stack heights reported in the risk assessment document was used in the analysis. The following stack heights, in meters, were included in the model runs: 7.6, 9.2, 11, 13, 15, 17, 19, 21.8, 23, 31, 47, and 61 m. The stack diameters and exit velocities associated with each of the stack heights were also used in the model, so that predicted ground concentrations would reflect actual sludge feed rates.

Stack height proved to be the most sensitive parameter for calculation of allowable sludge concentrations. For the tallest stack, at 61 m, the maximum increase in allowable sludge concentrations, due to stack height, was a factor of 99, when the MEI was located at the maximum ground concentration point; a factor of 28, when the MEI was located at 200 m; a factor of 6, when the MEI was located at 500 m; and a factor of 4, when the MEI was located at 1,000 m.

4.4.3 Third Sensitivity Analysis

The third sensitivity analysis examined the effect of gas temperature on maximum allowable sludge concentrations. Medium (21.8 m) and low (9.2 m) stacks were modeled with the meteorology and building dimensions of the reasonable worst-case facility using a low temperature of 310°K and a high temperature of 477°K. The 310°K represents the temperature expected when a wet scrubber is operating, while the 477°K represents the temperature expected when a dry pollution control device such as an electrostatic precipitator or baghouse is used.

The maximum increase in allowable sludge concentrations obtained between the two stack temperatures was a factor of 3, when the MEI was located at the maximum ground concentration point; a factor of 2, when the MEI was located at 200 m; a factor of 1.5, when the MEI was located at 500 m; and a factor of 1.2, when the MEI was located at 1,000 m.

4.4.4 Conclusions of Sensitivity Analyses

As a result of these sensitivity analyses, the Agency permitted allowable sludge pollutant concentrations to be calculated using a simplified air model that was based on stack height only. (In the proposed regulation, the Agency has also provided for changes in maximum allowable sludge concentrations, depending on the efficiency of a facility's pollution control devices. See Section 8 for more information on site-specific tests.)

4.5 GOOD ENGINEERING PRACTICE STACK HEIGHT (40 CFR §51.1(ii))

Good Engineering Practice (GEP) stack height standards were developed by the Agency to avoid the construction of very tall stacks built for the sole purpose of reducing excessive ground level ambient concentrations. As an integral part of determining the impact of incinerator emissions on ambient air quality, EPA's current requirements for the use of GEP stack height in air dispersion models must be considered.

Stacks that are shorter than 65 m are considered de minimis. For incinerators with such stacks, the actual stack height should be used in calculating emission limitations. Most current sludge incinerators have stacks shorter than 65 m.

For incinerators with stack heights in excess of 65 m, the following formulas must be used to determine the effective stack height for modeling purposes, as cited in 40 CFR 51.1(ii):

> "(a) for stacks in existence on January 12, 1979, and for which the owner or operator had obtained all applicable permits or approvals required under 40 CFR Parts 51 and 52.

$$H_g = 2.5H$$

provided the owner or operator produces evidence that this equation was actually relied on in designing the stack or establishing an emission limitation to ensure protection against downwash;

(b) for all other stacks,

$$H_g = H + 1.5L$$

where H_g = good engineering practice stack height, measured from the ground-level elevation at the base of the stack,

H = height of nearby structure(s) measured from the ground-level elevation at the base of the stack,

L = lesser dimension, height or projected width, of nearby structure(s),

provided that the EPA, State or local control agency may require the use of a field study or fluid model to verify GEP stack height for the source; or the height demonstrated by a fluid model or a field study approved by the EPA, State or local control agency, which ensures that the emissions from a stack do not result in excessive concentrations of any air pollutant as a result of atmospheric downwash, wakes, or eddy effects created by the source itself, nearby structures or nearby terrain features."

Sources and stacks in existence on December 31, 1970, are grandfathered and not subject to this regulation. The actual stack height at these facilities is considered to be the GEP height in the modeling calculations.

Because no sludge incinerators in the United States had stack heights in excess of 65 m prior to January 12, 1979, the "$Hg = 2.5H$" equation does not apply. The requirement to meet either the "$Hg = H + 1.5L$" or the fluid modeling requirement applies to any sludge incinerator with a stack height in excess of 65 m built after January 12, 1979.

SECTION FIVE

RISK METHODOLOGY FOR INCINERATION

A significant part of the process to develop the proposed regulation for sewage sludge incineration was formulating the methodology to evaluate the risk of incinerator emissions. This effort was undertaken jointly by EPA's Office of Water (OW) and the Office of Research and Development (ORD). The results are contained in the document Development of Risk Assessment Methodology for Municipal Sludge Incineration (EPA 1986e).

A summary of the risk methodology is contained in this section. Comments on the review of the methodology by the Scientific Review Board are also included in this section, with responses by OW and ORD.

Note that after publication, some aspects of the methodology as applied to the proposed incinerator regulation were revised. Some of the explanations contained in this section were, therefore, also revised to more clearly relate the methodology to the proposed regulation. For example, "risk-specific dose," a term presently used in assessing the health risks associated with sludge incineration, was previously termed "reference air concentration." The complete methodologies are contained in Appendix C.

5.1 METHODOLOGY SUMMARY AND SCOPE

The risk methodology addresses the health risks associated with sludge incineration practices. It contains information on the pathway evaluated, the databases that provided information on sludge incinerator facilites, the modeling techniques applied, the exposure criteria and assessment, and a sample calculation. It is structured to allow for the calculation of technical guidelines for sludge incineration, based on the potential for health or environmental impacts.

The overall risk assessment process involved:

- Defining sludge management practices and the most exposed individual, based on those practices
- Formulating a modeling procedure to which health effects and physiochemical data were applied to predict exposures and risk
- Determining allowable sludge concentrations or disposal rates, which would determine if management practices need to be revised or controlled

In general, risk assessment for a given chemical is based on exposure and dose-response assessments for each chemical. In this case, exposure assessment was determined by quantifying the incinerator source characteristics and modeling the degree of exposure through inhalation to sensitive individuals residing near the incinerator.

Dose-response assessment is geared toward protecting sensitive individuals and consists of methods to estimate toxicity thresholds and cancer potencies. These methods are well established within the Agency.

Health effects are then predicted based on the estimated exposure. In a reverse process, criteria, or allowable exposure for a certain level of risk are defined based on the health effects data. In terms of sludge incineration, reasonable worst-case scenarios were developed and used to predict health effects. The criteria are allowable increases in ambient ground-level concentrations or risk-specific doses. The RSDs are based on risk levels, cancer potency values, and body weight and inhalation rates of the MEI.

5.1.1 Pathway Evaluated

Inhalation was the primary pathway evaluated, although three other pathways were considered and discounted. The pathway for ash disposal was discounted because the ash is adequately controlled under the Resource Conservation and Recovery Act (RCRA)(40 CFR 257, 258, and 261-268). The scrubber water pathway was eliminated because the scrubber water is recycled into the front end of the wastewater treatment plant and is then treated. The deposition of incinerator emissions, mainly particulates, is considered a potential pathway of concern; but at present, methodologies to evaluate deposition and its impact on the environment and human health have not been fully developed. As models are refined, EPA will evaluate deposition impacts further.

5.1.2 Model Plants Database

To characterize the incinerator source of the emissions, a set of ten sludge incinerator plants was selected from an EPA-sponsored telephone survey of sludge incinerators (EPA, 1987a). (See Section 3 for a more detailed description of the database.) The ten plants were carefully selected to represent a cross-section of 127 operational plants identified in the survey. The selection of the plants was reviewed by both an EPA work group and by an external peer review committee.

The following factors were considered in selecting the plants:

- Furnace type
- Sludge burning capacity
- Air pollution control system type
- Stack heights
- Stack gas velocities
- Proximity of population to the facility

- Special terrain effects
- Potential for plume downwash
- Potential for adverse meteorological effects

Table 5-1 presents a summary of most of the relevant parameters for the ten modeled plants. It includes the dispersion factor for the MEI, expressed as the annual average ground-level concentration (ug/m^3) per unit emission rate (g/sec). Sections 7 and 8 contain explanations on how the dispersion factors were calculated for metals and THCs, respectively.

5.1.3 Air Dispersion Models

Air dispersion models were used to estimate average ground-level contamination concentrations of sludge pollutants. The air dispersion models used were EPA-approved versions of Industrial Source Complex Long Term (ISCLT), LONGZ, and COMPLEX I. These models were selected based on the following criteria developed by EPA, Model Development and Application Division (1986a):

- ISCLT is the only EPA-accepted model that considers the effect of building aerodynamic downwash. ISCLT, however, cannot handle complex terrain (terrain equal to or higher than the stack height).
- LONGZ supplements the ISCLT modeling results for the facilities that have complex terrain features in urban areas.
- COMPLEX I supplements ISCLT for complex terrain features in a rural setting.

See Section 4 for a comprehensive discussion on the models used to support the sludge incineration regulations.

The results of the LONGZ and COMPLEX I supplemental modeling were merged with those from the ISCLT modeling to account for both the effects of downwash and the unusual terrain effects around many of the facilities. Downwash is

TABLE 5-1. Relevant Parameters for the Ten Modeled Sludge Incinerator Facilities[a]

MODEL FACILITY CATEGORY	LOCATION	INCIN-ERATOR TYPE	NUMBER OF IN-CINER-ATORS	TOTAL CAPACITY (DRY METRIC TONS/DAY)	STACK HEIGHT (METERS)	STACK DIAMETER (METERS)	STACK TEMP. (°K)	STACK VELOCITY (METERS/ SEC.)	STACK FLOW (ACMS)	LAND USE	BUILDING DIMENSIONS (METERS)			DISPERSION FACTOR (MEI) (ug/m^3/g/sec)
											HEIGHT	LENGTH	WIDTH	
1	Arlington, VA	MHF	2	31.6	35.4	0.91	338	14.0	9.02	Urban	18.3	26.5	33.9	1.7
2	Gainesville, GA	Elect.	2	10.0	7.6	0.51	311	7.70	1.61	Rural	5.5	31.7	23.5	39.4
3	Dubuque, IA	FBI	2	13.6	16.2	0.61	308	11.83	3.45	Rural	10.7	54.9	54.9	26.7
4	Patapsco, Baltimore	MHF	3	89.4	21.8	0.91	308	7.70	5.11	Urban	16.3	54.9	14.1	6.87
5	Detroit, MI	MHF	14	982.0	22.0[b] 44.0	1.32	310[b] 307	14.3 15.7	19.6 21.5	Urban	29	82.0	62.0	1.35
6	Cincinnati, OH	MHF	4	153.1	23.3	0.8	325	20	10.12	Urban	18.3	73.2	55.5	3.69
7	Cleveland, Westerly	MHF	4	176.7	27.4	0.91	308	18.98	12.46	Urban	25.0	48.0	48.0	4.01
8	Greenbay, WI	MHF	2	79.5	55.1	1.52	329	11.3	20.5	Urban	18.3	36.6	36.6	5.39
9	Rocky Mount, NC	MHF	1	9.4	18.3	0.58	308	9.31	2.46	Rural	15.3	15.1	8.5	12
10	Port Washington, NY	FBI	1	25.3	9.2	0.46	308	10.10	1.66	Urban	6.8	29.3	28.5	9.08

[a] From EPA, 1986a.

[b] Complex I and Complex II at Detroit.

Note: MHF = Multiple-hearth furnace; FBI = Fluidized-bed incinerator; Elect. = Electric furnace.

very significant for most sludge incinerator facilities due to the predominance of very short stack heights above buildings.

5.1.4 Exposure, Dose, Risk, and Cancer Potency Criteria

Exposure, risk, and cancer potency values were determined and the reasonable worst-case dosage was defined to evaluate the potential health effects of the pollutants.

5.1.4.1 Exposure Level Criteria for the MEI

The exposure level for a contaminant dose for an individual residing in an area impacted by emissions from the municipal sludge incinerator depends on the following criteria:

- Duration of exposure
- Inhalation volume
- Particle size distribution for incinerator emissions
- Annual average contaminant concentrations

Duration of Exposure

Duration of exposure depends on three factors: the amount of time the MEI spends in a location impacted by the incinerator emissions, the percentage of time on an annual basis that the incinerator is operational, and the expected operating life of the system.

For this analysis, the MEI's duration of exposure was calculated on the assumption that the MEI resided in the area of maximum annual ground-level concentration and was exposed 24 hours (h) a day. The incinerator(s) was assumed to be operational for the life of the individual (70 years (yr)) and was on-stream 100% of the time. This 70-yr exposure was assumed valid since wastewater treatment plants are expected to be in operation indefinitely. The MEI was chosen for this analysis because the MEI exposure is the most conservative scenario available.

Inhalation Volume

Inhalation volume refers to the volume of air inspired on a daily basis. A volume of 20 cubic meters (m^3) per day was assumed, which was consistent with Agency analysis and calculations made by EPA's Cancer Assessment Group (CAG) for this assessment.

Particle Size Distribution

Particle size distribution refers to the size of the particulate emitted from the incinerator. For this analysis, it is assumed that 100% of the particles inhaled are retained in the lungs. This assumption is consistent with exposure calculations in other EPA studies.

Annual Average Contaminant Concentrations

For sludge incineration, ambient concentrations were predicted in terms of an annual average in micrograms per cubic meter (ug/m^3). The human exposure was assumed to be 100% of the annual average, which is consistent with EPA assumptions for exposures that were calculated for other Agency studies.

5.1.4.2 Dose Received by the MEI

As defined by CAG, lifetime inhalation exposures are estimated for a 70-kilogram (kg) man inhaling 20 m^3 of air daily, with 75% of the contaminant mass being absorbed into the body.

5.1.4.3 Risk Level Estimations for the MEI

The selection of a carcinogen risk level for the MEI is a controversial subject. Risk levels for 1×10^{-4} up to 1×10^{-7} have been discussed and used in a number of regulatory decisions by EPA and others. 1×10^{-5}, or the probability of 1 cancer case in 100,000 individuals, has been concluded by EPA to be a conservative public health goal. The use of a 1×10^{-5} risk has also been justified to account for the uncertainties and the assumptions typically used in risk calculations. EPA has selected a carcinogenic risk level of 1×10^{-5} for all carcinogens in this methodology and the proposed incinerator regulation.

5.1.4.4 Cancer Potency Values

The q_1* value for each chemical is usually an upper-bound estimate of the slope of the dose response curve in the low-dose range. The value is expressed in terms of risk per dose, where dose is in units of mg/kg/day. The cancer potency value has units of $(mg/kg/day)^{-1}$.

The CAG has previously derived cancer potency estimates for each potentially carcinogenic chemical that is currently being evaluated for sludge criteria. Therefore, in this methodology, no new effort was required to develop potency estimates. The CAG q_1*values are shown in Table 5-2. See Section 6.4.1 for information on how the cancer potency values were determined for THCs.

TABLE 5-2. Cancer Potency Values for Metals (q_1^*)

Metals	q_1^* (mg/kg/day)$^{-1}$
Arsenic	15.0
Beryllium	8.4
Cadmium	6.1
Hexavalent chromium	41.0
Nickel as nickel subsulfide	1.05

5.1.5 Risk-Specific Dose (RSD)

A risk-specific dose (RSD, in mg/m^3) is defined as an ambient air concentration of a carcinogen used to evaluate the potential for adverse effects on human health, as a result of sludge incineration. That is, for a given incinerator site and set of incinerator practice definitions and assumptions, sludge contaminant concentrations that are calculated to result in an increase of air concentrations above the RSD can be assumed to be a basis for concern in terms of the increase in adverse health effects to humans in the site vicinity.

An RSD is determined based on contaminant toxicity and air inhalation rate, from the following generalized equation:

$$RSD = \frac{RL \times BW}{q_1^* \times Ia} \qquad (1)$$

where RSD - risk-specific dose (ug/m^3)
RL - risk level (unitless)
BW - body weight (kg)
q_1^* - cancer potency (mg/kg body weight/day)$^{-1}$
Ia - inhalation rate (m^3/day)

This equation assumes that the inhaled contaminant is absorbed into the body through the lungs at the same rate in humans as in the experimental species tested, or is absorbed at the same rate through different routes of exposure (e.g., oral and inhalation). Also, this equation assumes that there is no other exposure to the contaminant from other sources, natural or manmade.

For development of sludge RSD values, EPA used the following values:

RL - 1×10^{-5} or one chance in 100,000 of developing cancer
BW - 70 kg, which is the standard body weight of an adult male
I_a - 20 m^3/day, which is the standard inhalation rate of an adult male during a normal day
q_1^*- individual cancer potency value for each pollutant

5.1.6 Example Calculation to Determine Sludge Concentrations

After modeling was completed, the highest annual ground-level concentrations were identified at each of the ten sites. The maximum allowable ambient concentrations for the pollutants of concern, calculated from the RSD, the results from air modeling runs, and the fraction of the pollutant emitted, based on the control efficiency of the incinerator, were then used to calculate the stack emission rates for a given pollutant. This calculation was done by applying simple ratios of the ambient concentrations and emission rates, because the modeling results are linearly related. See Section 7 for more information on control efficiencies.

To determine whether the emissions were acceptable, the modeled emission rates calculated for each plant were compared to the actual emissions determined by the testing of the sludge incinerators. If the RSDs were exceeded, some type of sludge pollutant criteria, management practice, or additional air pollution control practice (or all three) must be developed to reduce emissions.

This example calculation uses data for the carcinogen chromium, which is incinerated in sludge at Facility 7 (see Table 5-1). The Facility 7 site is located in an urban, industrialized area. Three incinerator flue stacks at the facility are taller than the critical height at which building aerodynamic downwash would be expected to increase near-source surface concentrations. The incinerator plant building is a complex structure with varying roof height. The total capacity of the four on-site incinerators is 176.7 dry metric tons/day.

Using the air dispersion model described previously, the dispersion factor for the MEI from the facility (under normal operating conditions) is estimated to be 4.01 ug/m^3 $(g/sec)^{-1}$ (from Table 5-1).

Equation 2 calculates the allowable concentration of chromium in sludge:

$$SC = \frac{RSD \times CF1}{DP \times FE \times FR} \tag{2}$$

where SC = allowable sludge concentration (mg/kg, dry weight)
RSD = risk-specific dose (ug/m^3)
CF$_1$ = conversion factor (86,400 g/day)
DP = dispersion modeling parameter (ug/m^3 (g/sec)$^{-1}$)
FE = fraction emitted (unitless), assuming 95% control efficiency (or 1 - 10th percentile control efficiency. (See Section 7 for a discussion on control efficiency.)
FR = feed rate (mg/day dry weight), assumption based on the design capacity of Facility 7

For Facility 7, the following values were substituted into equation 2:

RSD = 0.0034 ug/m^3
CF$_1$ = 86,400 (g/day)
DP = 4.01 ug/m^3 (g/sec)$^{-1}$ (from Table 5-1)
FE = (1 - 0.96 = 0.04) (see Table 7-2)
FR = 176.7 dry metric tons/day

$$SC = \frac{0.0034 \times 86,400}{4.01 \times 0.04 \times 176.7}$$

SC = 10.36 mg/kg

By this calculation, the chromium level in sludge must not exceed 10.3 mg/kg (ppm) on a dry matter basis.

5.2 COMMENTS AND RESPONSES ON THE SLUDGE INCINERATION METHODOLOGY

The Environmental Engineering Committee of EPA's Science Advisory Board (SAB) reviewed the risk methodologies for incineration, landfilling, land application, and ocean disposal. The SAB's major comments on incineration and the Office of Water and ORD's responses are summarized below. The review took place prior to the development of the sewage sludge surface impoundments regulation.

5.2.1 The LONGZ Model Predictions of Concentrations Above Stack Heights

SAB COMMENT: LONGZ excessively overpredicts concentrations at locations above stack height. Its use in rough terrain should be re-evaluated.

OW/ORD RESPONSE: LONGZ was selected for the incineration risk assessment because it is the model recommended by EPA's Office of Air Quality Planning and Standards for use in complex terrain in urban areas, as cited in EPA's Guidelines on Air Quality Models (1986c). The only approaches currently available for calculating ground-level concentrations in complex terrain are to modify a flat terrain Gaussian plume model or to develop a numerical model that considers variations in terrain height over the calculation grid. Both approaches provide only a simple approximation of plume-terrain interaction because these processes are not well understood.

LONGZ is a modified Gaussian plume model that is much easier to use than a numerical model and should be just as accurate given our current state of knowledge. Comparisons of LONGZ predictions of downwind pollutant concentrations with observed data do not indicate that LONGZ overpredicts excessively. This information is contained in Appendix H of the User's Instructions for the SHORTZ and LONGZ Computer Programs (EPA, 1982).

In the risk assessment, the MEI is defined as living wherever maximum ground concentrations are predicted by the models. Because of this definition, sludge concentrations will not generally be limited by complex terrain effects. Because most sludge incinerators have short stacks, building downwash rather than complex terrain effects generally causes the highest ground concentrations and therefore limits sludge concentrations. The MEI would have to be redefined as living beyond the effects of downwash before complex terrain would affect maximum ground concentration of pollutants and, in turn, limit allowable sludge concentrations.

5.2.2 Model Predictions of Nonsteady Incinerator Operations

SAB COMMENT: The models should be able to predict the effects on ground concentrations of nonsteady operation of the incinerator.

OW/ORD RESPONSE: The existing risk assessment and modeling approach was designed to predict long-term effects over the MEI's 70-yr lifespan. Short-term fluctuations in pollutant concentrations are potentially a matter of concern, but adequate data are not yet available to include them in the methodology. The effects of short-term fluctuations will be evaluated in the future when monitoring data are available.

5.2.3 Consideration of Particulate Emissions

SAB COMMENTS: Are particulates or vapors plus particulates considered in the models?

The risk assessment is using a very questionable assumption that all particulates in the emissions are of a size enabling complete uptake by the lung.

The risk assessment is flawed by not including deposition pathways for particulates.

OW/ORD RESPONSE: The risk assessment methodology now makes the worst-case assumption for inhalation that the incinerator emits only vapors and particulates that are less than 10 u in diameters. Once the assumption is made that all the particulates are this small, it follows that all can be completely taken up by the lung. EPA will evaluate deposition pathways when a reliable model has been developed.

5.2.4 Model Inclusion of Air Pollution Control Devices

SAB COMMENT: Air pollution control devices should be included in the models (e.g., afterburners).

OW/ORD RESPONSE: The effect of air pollution control devices combined with wet scrubbers is included in the calculation of sludge concentrations after the air model is run. The model is run using a 1 g/sec emission rate. The maximum predicted ground concentration is adjusted for each pollutant using the ratio of the expected emission rate for that chemical, divided by the 1 g/sec value used in the model. The maximum allowable sludge concentrations that will produce those ground concentrations are then back-calculated by adjusting for air pollution control efficiency and sludge feed rate.

The Office of Water is currently in the process of collecting efficiency data from afterburners and other control devices. The effect of afterburners when a wet scrubber is not included in the design must be taken into consideration both before and after the model is run. Model input before the model is run with a 1 g/sec emission rate must include the higher temperature and velocity of the gas caused by the afterburner when a wet scrubber is not available to reduce the temperature. This adjustment factor can then be used on model output to back-calculate pollutant-specific maximum allowable sludge concentrations.

5.2.5 Consideration of Ecosystem on Secondary Human Impacts

SAB COMMENT: The risk assessment is flawed by not considering ecosystem or secondary human impacts.

OW/ORD RESPONSE: The MEI is defined as such a worst-case situation that primary human impact should generally be the limiting factor for sludge incineration. EPA's Environmental Criteria and Assessment Office (ECAO) has just developed an exposure assessment model that uses the deposition predictions from the ISCLT air model to evaluate food chain, surface runoff, and ground-water effects. Once this assessment has been reviewed and approved by SAB, OW will consider using it for the sludge regulation.

SECTION SIX

DEVELOPMENT OF RISK-SPECIFIC DOSES (RSDs)

The numeric limits for metals and total hydrocarbons are based, in part, on risk-specific doses. For a given pollutant, an RSD is the maximum allowable annual increase in ground-level ambient air concentration when sewage sludge is incinerated. RSD values are set independently of any background concentrations.

Ambient air concentrations, expressed as annual averages, must be below levels that could adversely affect human health based on long-term exposure to the emissions. Annual averages are used because it has been shown that annual average concentrations are essentially the same as lifetime concentrations, carcinogen risks are based on lifetime (70-yr) exposures and all but two of the pollutants of concern are carcinogenic when inhaled.

Although the basis for the RSD calculation is the same for all pollutants addressed in the proposed regulation, the RSD calculations vary in several ways. For arsenic, cadmium, chromium, and nickel, the RSDs are derived from a predefined risk level, cancer potency values, and body weight and inhalation rate of the MEI. For lead, which is not currently considered a carcinogen (40 CFR 50.12), the RSD is derived as a percentage of the NAAQS. For THCs, the RSD calculation is the same as for all metals except lead; however, the cancer potency value is derived in a way to represent all organics in one RSD value and contains data on carcinogens and noncarcinogens.

RSDs were not developed for mercury or beryllium because the Agency has promulgated NESHAPs for these pollutants (40 CFR §61.50 and 40 CFR §61.30). NESHAP values are already expressed as emission rates (gm/24 hr).

6.1 RSD CALCULATION FOR CARCINOGENS

Carcinogenicity is a long-term health effect usually requiring many years of human exposure prior to development. Therefore, to develop the RSDs for carcinogens, EPA evaluated the effects of chronic exposure rather than short-term acute exposure.

The RSD equation is as follows:

$$RSD = \frac{RL \times BW}{q_1^* \times I_a} \times 1{,}000 \qquad (3)$$

where RSD - risk-specific dose (mg/m^3)
RL - risk level: 1×10^{-5}, or 1 chance in 100,000 of developing cancer
BW - body weight: 70 kg, or is the standard body weight of an adult male
q_1^* - individual potency value for each pollutant, $(mg/kg/day)^{-1}$, from Table 5-2
I_a - inhalation rate, or 20 m^3/day, which is the standard inhalation rate of an adult male during a normal day
1,000 - conversion of mg to ug

6.1.1 Sample RSD Calculation for Carcinogens

As an example, the derivation of the RSD for arsenic is shown.

$$RSD\ (Arsenic) = \frac{(1 \times 10^{-5}) \times 70\ kg}{15.0\ mg/kg/day^{-1} \times 20\ m^3/day} \times 1{,}000$$

$$RSD\ (Arsenic) = 0.0023\ ug/m^3$$

The RSDs for cadmium, chromium, and nickel were derived in an identical manner.

6.1.2 Nickel and Chromium

Both nickel and chromium emissions from sludge incinerators present a specific problem in establishing an RSD. In the calculations, EPA assumed that 1% of the emission of chromium in sludge is in its most toxic form, hexavalent chromium. For nickel in sludge, the Agency assumed that 100% of the nickel emissions are in the toxic nickel subsulfide form.

Chromium is likely to be emitted in either the highly carcinogenic, hexavalent state (Cr^{+6}) or in the noncarcinogenic trivalent state (Cr^{+3}). Trivalent chromium compounds have not been shown to be carcinogenic and trivalent chromium toxicity is prevalent only at levels higher than those normally found in sewage sludge or emitted from sewage sludge incinerators. Although the hexavalent state (as the most oxidized form) could be expected to result from combustion, investigators speculate that most of the chromium is instead very likely to be emitted in the trivalent state because the former is more highly reactive (and thus likely to react with reducing agents to form the latter).

6.1.2.1 Chromium Conversion to Hexavalent Chromium

Several studies have been conducted on the potential for chromium in sludge to be converted into its more toxic hexavalent form. These studies, some of which have been funded by EPA, are of two types:

- Tests of incinerator emissions for total chromium and hexavalent chromium
- Laboratory trials for evaluating the conversion of chromium to the hexavalent state

Emissions tests for hexavalent chromium have been successfully conducted at two sludge incinerators -- one in Detroit, Michigan, and one in Cincinnati, Ohio. The emissions test at the Detroit incinerator did not detect any hexavalent chromium in the stack emission, although the analytical detection limit was 10 ppm (EPA, 1985). At Cincinnati, however, the test did detect a significant amount of hexavalent chromium in the total chromium emissions (EPA, 1987a): two sampling runs averaged a 13% hexavalent-to-total-chromium ratio.

EPA sponsored a laboratory study of the conversion of chromium to hexavalent chromium in the sludges from two different cities (Drees, 1988). During the testing, which was conducted in a laboratory muffle furnace, the two sludges were dosed with lime (CaOH) and ferric chloride. These substances are used at many wastewater treatment plants as sludge conditioners prior to dewatering.

The analysis of combusted sludges dosed with various levels of lime and ferric chloride revealed that the hexavalent-to-total-chromium ratio increased with lime dosage. One hundred percent conversion of chromium to hexavalent chromium was observed in several of the tests. These tests indicate that chromium can be converted to hexavalent chromium under incinerator operating conditions and that the percent conversion can be quite high.

According to a review of the literature, two similar laboratory tests have been conducted in Japan in which sludge was subjected to combustion conditions with various lime doses (Umastima et al., 1975; Majima et al., 1977). This work supported EPA work by also demonstrating high conversions of chromium in the sludge to the hexavalent form when it was exposed to incinerator-type conditions in the laboratory.

The above results have led EPA to assume that, for this regulation, the chromium emissions from a reasonable worst-case sludge incinerator are 1% hexavalent chromium. To determine this value, the geometric mean of the two incinerator test results, 10 ppm (1×10^{-5}) and 13% (130,000 ppm) or 1.3×10^{-1}, was calculated to be 0.11% hexavalent chromium to total chromium. To determine the geometric mean, the results were added to equal 1.3×10^{-6}. The square root of 1.3×10^{-6} was taken, which is 1.4×10^{-3} or approximately 0.001.

This figure is 1/10 of a percent of .11%. This mean value was multiplied by a safety factor of 10 to give the 1% hexavalent-to-total-chromium ratio.

EPA plans to perform additional tests of sewage sludge incinerator emissions for hexavalent chromium before this proposed rule is finalized. The additional data should allow the Agency to better understand how hexavalent chromium is generated in sewage sludge incinerators.

6.1.2.2 Nickel

The Agency has ongoing studies on the health effects of nickel compounds emitted from combustion sources. These studies are evaluating a number of nickel compounds and their health effects. Unless they indicate otherwise, the Agency will assume that all emitted nickel compounds cause the same health effects as the highly carcinogenic compound nickel subsulfide.

As additional data become available on the form of chromium and nickel emissions from combustion sources, the Agency will consider what changes, if any, would be appropriate for these proposed regulations.

6.2 RSD CALCULATION FOR LEAD

The RSD for lead is based on the National Ambient Air Quality Standard (NAAQS) for lead, currently 1.5 ug/m^3 (40 CFR 50.12). This level is designed to ensure that 99% of the population has blood lead levels below 15 micrograms per deciliter (ug/dl), the level estimated to cause adverse health effects. To determine the RSD, the NAAQS for lead (1.5 ug/m^3) is divided by a factor of 4. Thus the RSD for lead is 0.38 ug/m^3.

EPA now has data indicating that levels of lead in blood less than 10 ug/dl can produce a variety of toxic lead effects, particularly in the very young. In light of this new information, the Agency has begun studies to determine if the current NAAQS for lead needs to be revised. Until a new NAAQS is promulgated, the current NAAQS will be the basis of the numeric limit for lead when sewage sludge is incinerated.

In proposing this numeric limit for lead, the Agency considered the proportion of the NAAQS that should be assigned to sewage sludge incinerators. The Agency considered two alternatives: 10%, the percentage used in the proposed revisions to the Hazardous Waste Incinerator Regulation (see -- FR ----, ---- --, 1988), and 25%.

Currently, States allocate a percentage of the NAAQS to various sources of lead emissions in nonattainment areas through State Air Implementation Plans (SIPs). Up to now, States have not included limits for sewage sludge incinerators in their SIPs. As a result, the Agency has assumed that States do not consider sewage sludge incinerators as significant sources of lead emissions. EPA is, therefore, proposing 25% of the NAAQS as the initial limit to be used in regulating lead from sewage sludge incinerators.

Limiting lead emissions from sewage sludge incinerators to 25% of the NAAQS ensures that the annual increase for lead in ground-level ambient concentrations would not exceed 0.38 ug/m^3. States, however, may further limit the emission of lead from sewage sludge incinerators, if the change is warranted in nonattainment areas. When EPA revises the current NAAQS of 1.5 ug/m^3, the Agency will also revise the sludge incineration numeric limit for lead.

6.3 MERCURY AND BERYLLIUM

Beryllium and mercury are regulated under NESHAPS, 40 CFR Part 61, Subpart C and Subpart E, respectively. The NESHAPS for both mercury and beryllium emissions from sludge incinerators are stated as emission rates in terms of grams per 24 hr. 40 CFR §61.50 sets a limit for mercury emissions of 3200 g/24-hr period, and 40 CFR §61.30 specifies a beryllium limit of 10 g/24-hr period.

In evaluating the risks of mercury and beryllium emissions from sludge incineration, the Agency confirmed that the emission rates developed in NESHAPs were adequate to meet the same inhalation risks as for the other metal pollutants in this rule. Thus RSDs for mercury and beryllium have not been developed for sludge incinerators, and these values are not needed to determine compliance with the proposed incinerator regulation.

6.4 RSDs FOR TOTAL HYDROCARBONS

To develop a risk-based emission standard for THCs, assessment of the health impact of THC emissions from sludge incinerators was necessary. Like the allowable sludge concentration limits for metals, a 1 x 10^{-5} risk level was used to determine the THC risk-based emissions standard.

6.4.1 THC Cancer Potency Value

The THC cancer potency value is representative of all compounds that have the potential to create an adverse health effect and be emitted from a sewage sludge incinerator. EPA considers two types of compounds that create adverse health effects -- carcinogens and noncarcinogens.

For carcinogens, the level of exposure determines the cancerous effect. For toxic compounds not known to have carcinogenic properties, a threshold concentration exists. Below the threshold concentration, no adverse health effects are known to occur. Protection against the adverse health effects of a noncarcinogen results from ensuring that the concentration level does not exceed the threshold dose.

The THC cancer potency value was calculated using data from four incinerator tests as well as theoretical data for the organics that were not detected in the tests. (See Table 3-1, Studies 13-16.) For each of the 21 detected compounds, the investigators determined the 95th percentile concentration. If a compound was only detected once, the single-point concentration was used.

Carcinogens and noncarcinogens are included in the cancer potency value calculation to accurately relate the instrument reading of total THCs at the incinerator to health impacts. As described below, the value is weighted to account for the differences between the health impacts of carcinogens and noncarcinogens.

6.4.1.1 Carcinogens

To account for the potency of the undetected organics, data for all the known organic carcinogens for which inhalation health effects potency data have been gathered were added to the list of 21 detected compounds at the 0.1 nanogram per liter (ng/l) limit. These include:

- All carcinogens identified in EPA's IRIS system with inhalation health effects data (potencies), which were included at an assumed detection limit of 0.1 ng/l. (IRIS is EPA's database of chemical risk assessment information.)

- Formaldehyde, which has been detected in the emissions of both municipal waste incinerators and hazardous waste incinerators but was not measured during the four sludge incinerator emissions tests. Concentrations for formaldehyde are based on data from tests of municipal solid waste and hazardous waste incinerators.

- Methane (C_1) and ethane, ethylene, and acetylene (C_2), which are known to be emitted in significant quantities from all combustion sources. This class of compounds was not measured during the sludge incinerator tests. To account for their presence in the stack gases, EPA combustion data from fossil-fueled boilers, furnaces, and other sources were reviewed. The 95th percentile concentrations of the C_1 and C_2 fractions were calculated. The values are shown in Table 6-1.

TABLE 6-1. 95th Percentile Concentrations of the C_1 and C_2 Fractions (Generic Risk Calculations with Two Significant Figures)

Carcinogens	q* (day-kg/mg)	95% Emission Conc. (ng/L)	Weight Fraction	Weighted q* (day-kg/mg
Acrylamide	2.4E-01	0.1	1.8E-06	4.3E-07
Acrylonitrile	1.8E-01	1024.7	1.8E-02	3.2E-03
Aldrin	1.8E+01	0.1	1.8E-06	3.1E-05
Aniline	2.5E-02	0.1	1.8E-06	4.4E-08
Benzene	2.9E-02	309.89	5.5E-03	1.6E-04
Benzidine	2.3E+02	0.1	1.8E-06	4.1E-04
Benzo(a)pyrene	1.2E+01	17.49	3.1E-04	3.6E-03
Bis(2-chloroethyl) ether	1.2E+00	0.1	1.8E-06	2.1E-06
Bis(chloromethyl) ether	2.2E+02	0.1	1.8E-06	3.9E-04
Bis(2-ethylhexyl) phthalate	8.4E-04	47.1	8.3E-04	7.0E-07
1,3-Butadiene	9.7E-01	0.1	1.8E-06	1.7E-06
Carbon tetrachloride	1.3E-01	1.86	3.3E-05	4.3E-06
Chlordane	1.3E+00	0.1	1.8E-06	2.3E-06
Chloromethane	1.2E-02	450	8.0E-03	9.6E-05
Chloroform	8.1E-02	211.85	3.8E-03	3.1E-04
Chloromethyl methyl ether	9.5E+00	0.1	1.8E-06	1.7E-05
DDD	2.4E-01	0.1	1.8E-06	4.2E-07
DDE	3.4E-01	0.1	1.8E-06	6.0E-07
DDT	3.4E-01	0.1	1.8E-06	6.0E-07
1,2-Dibromo-3-chloropropane	2.2E+01	0.1	1.8E-06	3.9E-05
1,2-Dibromoethane	7.8E-01	0.1	1.8E-06	1.4E-06
1,2-Dichloroethane	9.1E-02	0.98	1.7E-05	1.6E-06
1,1-Dichloroethylene	1.2E+00	1.03	1.8E-05	2.1E-05
Dieldrin	1.6E+01	0.1	1.8E-06	2.8E-05
Diethylstilbestrol	4.9E+02	0.1	1.8E-06	8.7E-04
Dioxane	4.9E-03	0.1	1.8E-06	8.7E-09
1,2-Diphenylhydrazine	8.0E-01	0.1	1.8E-06	1.4E-06
Epichlorohydrin	4.2E-03	0.1	1.8E-06	7.5E-09
Ethylene oxide	3.5E-01	0.1	1.8E-06	6.2E-07
Formaldehyde	4.4E-02	780	1.4E-02	6.0E-04
Heptachlor	4.5E+00	0.1	1.8E-06	8.0E-06
Heptachlor epoxide	9.1E+00	0.1	1.8E-06	1.6E-05
2,3,7,8-Heptachlorodibenzo-p-dioxin	1.8E+02	0.00052	9.2E-09	1.6E-06
other-Heptachlorodibenzo-p-dioxin	1.8E+00	0.00060	1.1E-08	1.9E-08
Hexachlorobutadiene	7.8E-02	0.1	1.8E-06	1.4E-07
alpha-Hexachlorocyclohexane	6.3E+00	0.1	1.8E-06	1.1E-05
beta-Hexachlorocyclohexane	1.8E+00	0.1	1.8E-06	3.3E-06
gamma-Hexachlorocyclohexane	1.3E-01	0.1	1.8E-06	2.3E-07
Hexachlorocyclohexane, technical	1.8E+00	0.1	1.8E-06	3.1E-06
2,3,7,8-Hexachlorodibenzo-p-dioxin	6.2E+03	0.00051	9.0E-09	5.6E-05
other-Hexachlorodibenzo-p-dioxin	7.0E+01	0.00220	3.9E-08	2.7E-06
Hexachloroethane	1.4E-02	0.77	1.4E-05	1.9E-07
3-Methylcholanthrene	9.5E+00	0.1	1.8E-06	1.7E-05
Methylene chloride	1.5E-02	83.75	1.5E-03	2.2E-05
4,4-Methylene-bis-2-chloroaniline	1.7E-01	0.1	1.8E-06	3.0E-07
Methyl hydrazine	1.2E+00	0.1	1.8E-06	2.1E-06
2-Nitropropane	2.0E+02	0.1	1.8E-06	3.5E-04
N-Nitrosodi-n-butylamine	5.6E+00	0.1	1.8E-06	9.8E-06

TABLE 6-1. 95th Percentile Concentrations of the C_1 and C_2 Fractions (Generic Risk Calculations with Two Significant Figures)

Carcinogens	q* (day-kg/mg)	95% Emission Conc. (ng/L)	Weight Fraction	Weighted q* (day-kg/mg
Acrylamide	2.4E-01	0.1	1.8E-06	4.3E-07
Acrylonitrile	1.8E-01	1024.7	1.8E-02	3.2E-03
Aldrin	1.8E+01	0.1	1.8E-06	3.1E-05
Aniline	2.5E-02	0.1	1.8E-06	4.4E-08
Benzene	2.9E-02	309.89	5.5E-03	1.6E-04
Benzidine	2.3E+02	0.1	1.8E-06	4.1E-04
Benzo(a)pyrene	1.2E+01	17.49	3.1E-04	3.6E-03
Bis(2-chloroethyl) ether	1.2E+00	0.1	1.8E-06	2.1E-06
Bis(chloromethyl) ether	2.2E+02	0.1	1.8E-06	3.9E-04
Bis(2-ethylhexyl) phthalate	8.4E-04	47.1	8.3E-04	7.0E-07
1,3-Butadiene	9.7E-01	0.1	1.8E-06	1.7E-06
Carbon tetrachloride	1.3E-01	1.86	3.3E-05	4.3E-06
Chlordane	1.3E+00	0.1	1.8E-06	2.3E-06
Chloromethane	1.2E-02	450	8.0E-03	9.6E-05
Chloroform	8.1E-02	211.85	3.8E-03	3.1E-04
Chloromethyl methyl ether	9.5E+00	0.1	1.8E-06	1.7E-05
DDD	2.4E-01	0.1	1.8E-06	4.2E-07
DDE	3.4E-01	0.1	1.8E-06	6.0E-07
DDT	3.4E-01	0.1	1.8E-06	6.0E-07
1,2-Dibromo-3-chloropropane	2.2E+01	0.1	1.8E-06	3.9E-05
1,2-Dibromoethane	7.8E-01	0.1	1.8E-06	1.4E-06
1,2-Dichloroethane	9.1E-02	0.98	1.7E-05	1.6E-06
1,1-Dichloroethylene	1.2E+00	1.03	1.8E-05	2.1E-05
Dieldrin	1.6E+01	0.1	1.8E-06	2.8E-05
Diethylstilbestrol	4.9E+02	0.1	1.8E-06	8.7E-04
Dioxane	4.9E-03	0.1	1.8E-06	8.7E-09
1,2-Diphenylhydrazine	8.0E-01	0.1	1.8E-06	1.4E-06
Epichlorohydrin	4.2E-03	0.1	1.8E-06	7.5E-09
Ethylene oxide	3.5E-01	0.1	1.8E-06	6.2E-07
Formaldehyde	4.4E-02	780	1.4E-02	6.0E-04
Heptachlor	4.5E+00	0.1	1.8E-06	8.0E-06
Heptachlor epoxide	9.1E+00	0.1	1.8E-06	1.6E-05
2,3,7,8-Heptachlorodibenzo-p-dioxin	1.8E+02	0.00052	9.2E-09	1.6E-06
other-Heptachlorodibenzo-p-dioxin	1.8E+00	0.00060	1.1E-08	1.9E-08
Hexachlorobutadiene	7.8E-02	0.1	1.8E-06	1.4E-07
alpha-Hexachlorocyclohexane	6.3E+00	0.1	1.8E-06	1.1E-05
beta-Hexachlorocyclohexane	1.8E+00	0.1	1.8E-06	3.3E-06
gamma-Hexachlorocyclohexane	1.3E-01	0.1	1.8E-06	2.3E-07
Hexachlorocyclohexane, technical	1.8E+00	0.1	1.8E-06	3.1E-06
2,3,7,8-Hexachlorodibenzo-p-dioxin	6.2E+03	0.00051	9.0E-09	5.6E-05
other-Hexachlorodibenzo-p-dioxin	7.0E+01	0.00220	3.9E-08	2.7E-06
Hexachloroethane	1.4E-02	0.77	1.4E-05	1.9E-07
3-Methylcholanthrene	9.5E+00	0.1	1.8E-06	1.7E-05
Methylene chloride	1.5E-02	83.75	1.5E-03	2.2E-05
4,4-Methylene-bis-2-chloroaniline	1.7E-01	0.1	1.8E-06	3.0E-07
Methyl hydrazine	1.2E+00	0.1	1.8E-06	2.1E-06
2-Nitropropane	2.0E+02	0.1	1.8E-06	3.5E-04
N-Nitrosodi-n-butylamine	5.6E+00	0.1	1.8E-06	9.8E-06

TABLE 6-1. (Continued)

Noncarcinogens	(day-kg/mg)	Conc. (ng/L)	Fraction	(day-kg/mg)
Isobutyl alcohol	0.0E+00	0.1	1.8E-06	0.0E+00
Isophorone	0.0E+00	0.1	1.8E-06	0.0E+00
Methomyl	0.0E+00	0.1	1.8E-06	0.0E+00
Methoxychlor	0.0E+00	0.1	1.8E-06	0.0E+00
Methyl ethyl ketone	0.0E+00	173.61	3.1E-03	0.0E+00
Methyl parathion	0.0E+00	0.1	1.8E-06	0.0E+00
Nitrobenzene	0.0E+00	0.1	1.8E-06	0.0E+00
Pentachlorobenzene	0.0E+00	0.1	1.8E-06	0.0E+00
Pentachlorophenol	0.0E+00	77.37	1.4E-03	0.0E+00
Phenol	0.0E+00	119.25	2.1E-03	0.0E+00
N-phenylenediamine	0.0E+00	0.1	1.8E-06	0.0E+00
Phenylmercuric acetate	0.0E+00	0.1	1.8E-06	0.0E+00
Pyridine	0.0E+00	0.1	1.8E-06	0.0E+00
Selenourea	0.0E+00	0.1	1.8E-06	0.0E+00
Strychnine	0.0E+00	0.1	1.8E-06	0.0E+00
1,2,4,5-Tetrachlorobenzene	0.0E+00	0.1	1.8E-06	0.0E+00
2,3,4,6-Tetrachlorophenol	0.0E+00	0.1	1.8E-06	0.0E+00
Tetraethyl lead	0.0E+00	0.1	1.8E-06	0.0E+00
Toluene	0.0E+00	215.02	3.8E-03	0.0E+00
1,2,4-Trichlorobenzene	0.0E+00	29.85	5.3E-04	0.0E+00
1,1,1 Trichloroethane	0.0E+00	97.5	1.7E-03	0.0E+00
Trichlorofluoromethane	0.0E+00	0.1	1.8E-06	0.0E+00
2,4,5-Trichlorophenol	0.0E+00	0.1	1.8E-06	0.0E+00
C1 Hydrocarbons	0.0E+00	17575	3.1E-01	0.0E+00
C2 Hydrocarbons	0.0E+00	34200	6.1E-01	0.0E+00
Total Noncarcinogens		53173.45		
TOTAL		56475.36865		1.3E-02 = q_1^*
Weighted Unit Risk				

6.4.1.2 Noncarcinogens

The next step in the calculation was to add organic compounds with known threshold health effects (i.e., noncarcinogens) to the list, also at the 0.1 ng/l limit. As threshold health effects compounds, they do not have a potency value. Instead, they have a health impact only above a minimum concentration level that is unique for each compound.

EPA has defined risk-specific doses of noncarcinogens as a fraction of the threshold concentrations. Also, for this calculation, the Agency assumed that the actual ambient air concentration of any threshold compound does not have any adverse health effects and that these threshold compounds would never be emitted at levels high enough to cause a health impact on the MEI. Therefore, in Table 6-1, a zero is used in the weighted cancer potency column for the noncarcinogens.

6.4.1.3 THC Weighted Cancer Potency Value Calculation

The concentrations from all of the above compounds were summed to obtain a total concentration of organics in the exhaust gas. The weighted fraction of each carcinogen was calculated by dividing the individual concentration by the total concentration. The weighted fraction for each individual compound was then multiplied by its potency to give a weighted fraction potency. These weight fractions were then totaled to give an overall potency value (q_1*) for the organic mixture. The calculated q_1* value is 1.3×10^{-2} (day-kg)/mg.

All the data and calculations are shown in Table 6-1. The total weighted potency value is indicated at the bottom of the list. Appendix D contains the complete documentation for computing the weighted potency value for THCs.

6.4.2 Conversion of Cancer Potency Values to RSDs

To calculate the allowable emission standard for THCs in sludge incinerators, the weighted cancer potency value must be converted to a risk-specific dose. The RSD is calculated as follows:

$$RSD = \frac{(1\times10^{-5}) \times 70}{q_1^* \times 20} \times 1{,}000 \qquad (4)$$

where RSD - risk-specific dose, ug/m^3
1×10^{-5} - acceptable risk level for the most exposed individual
70 - average body weight, kg
q_1^* - cancer potency value, (day-kg)/mg
20 - daily inhalation rate, m^3/day

(See Section 5 for more information on calculating the RSD.)

Substituting the cancer potency value, 1.3×10^{-2}, from Table 6-1, the RSD for THCs is 2.69 ug/m^3.

SECTION SEVEN

DEMONSTRATING COMPLIANCE WITH ALLOWABLE SLUDGE CONCENTRATION FOR METALS

The requirements for EPA's proposed incinerator regulations are based on owner/operator determinations concerning the concentrations of seven metal pollutants in incinerated sludge. Emissions cannot exceed the ambient ground-level concentrations around the facility (the RSD), 25% of the NAAQS value for lead, or NESHAP emission rates for mercury and beryllium. The facility may demonstrate compliance with the RSDs at one of three levels of complexity.

At the first and simplest level, the owner/operator may use the dispersion factor and control efficiencies contained in the proposed regulation, based on a simplified air dispersion analysis technique. If the facility cannot demonstrate compliance with allowable sludge concentrations at this level, the owner/operator may then develop site-specific values for dispersion factors while using the control efficiencies provided in the regulation. If compliance still cannot be demonstrated at this second level, site-specific tests for dispersion factors and control efficiencies may both be used. This third level requires performance tests and stack sampling of incinerator emissions to compute control efficiencies.

7.1 BASIC EQUATION FOR DETERMINING COMPLIANCE

The basic equation for determining compliance is:

$$C_i = \frac{RSD_i \times 86{,}400}{DF \times (1-CE_i) \times SF} \qquad (5)$$

where C_i = allowable sludge concentration of sludge pollutant i, dry basis (mg/kg)

RSD_i = risk-specific dose for pollutant i (ug/m^3), the given environmental criteria

DF = dispersion factor ug/m^3 (g/sec)$^{-1}$, from the air models

CE_i - overall system control efficiency for pollutant i (dimensionless)
SF - maximum sludge feed rate (Mg/day) dry basis

The two variables DF and CE_i are determined for the facility and are combined in equation 1 with the RSDs for each of the pollutants being regulated. The resulting set of allowable metal pollutant concentrations in sludge is then compared with the actual pollutant concentrations in the facility's sludge to determine compliance with the environmental standard. Sludge feed rates are discussed in Section 9 with other incinerator management practices.

7.1.1 Reasonable Worst-Case Control Efficiencies

The control efficiency for an incinerator directly relates the quantity of a pollutant in the sludge that is fed into an incinerator to the quantity of the pollutant emitted from the incinerator stack. Thus if the sludge contains 100 ppm lead and only 1 ppm is emitted, the incinerator is calculated to have a 99% control efficiency for lead.

The control efficiency for each pollutant must be known in order to relate the allowable stack emission rate to the concentration of the pollutant in the sludge. To reduce the testing burden on many sewage sludge incinerators, the Agency decided to develop a reasonable worst-case control efficiency for the metal pollutants being regulated. For determining compliance, a facility has the option of using EPA's reasonable worst-case control efficiencies in the compliance calculation or testing the incinerator(s) to obtain a site-specific control efficiency.

Using data from the air emissions control database (see Section 3), a set of summary statistics on incinerator control efficiencies for metals was generated across all incinerators and all references. From the database, EPA devised a set of 10th percentile control efficiencies, which the Agency has determined to be a reasonable worst-case situation representative of all sewage sludge incinerators. The control efficiency for each pollutant i was calculated as follows:

$$CE_i = 100 - \frac{\text{emission rate of pollutant i (mg/hr)}}{\text{feed rate of pollutant i (mg/hr)}} \times 100 \qquad (6)$$

If a metal was not detected (nondetectable, ND) in the database, the computations were handled as follows:

- Observations with a nondetected feed concentration were excluded from the analysis.

- Emission rates were set to zero for those measurements having a quantified feed and a nondetectable emission rate, which resulted in a destruction efficiency of 100%.

The summary statistics are presented in Table 7-1, which contains information on the number of observations, minimum, mean, median, maximum, standard deviation, and log normal 10th percentile.

In Table 7-1, the statistics for mercury show negative removal efficiencies as a result of a single negative removal efficiency of -298.5% from Reference 10 of the air emissions database. (See Table 3-1 for a list of studies reviewed.)

Appendix E contains the complete report describing how the control efficiencies were calculated.

For use as reasonable worst-case control efficiencies, the log normal 10th percentile values taken from this analysis are as follows:

- Arsenic - 96%
- Cadmium - 65%
- Chromium - 96%
- Lead - 67%
- Nickel - 95%

TABLE 7-1. Descriptive Statistics on Mean Incinerator Removal Efficiencies Across Incinerator and Reference Document

CONTAMINANT	NUMBER OF INCINERATORS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	LOGNORMAL 10TH PCT
ALUMINUM	7	95.48	99.22	99.92	100.00	1.67	97.06
ANTIMONY	7	99.32	99.78	99.84	100.00	0.25	99.46
ARSENIC	7	93.90	98.62	99.89	100.00	2.40	95.52
BARIUM	7	99.53	99.85	99.85	99.99	0.18	99.62
BERYLLIUM	4	99.98	99.99	100.00	100.00	0.01	99.98
BROMINE	1	99.90	99.90	99.90	99.90	.	.
CADMIUM	24	40.25	88.54	96.27	99.98	15.83	65.15
CAESIUM	1	99.98	99.98	99.98	99.98	.	.
CALCIUM	7	99.34	99.88	99.98	100.00	0.24	99.57
CERIUM	1	99.98	99.98	99.98	99.98	.	.
CHLORINE	4	99.44	99.69	99.52	99.98	0.25	99.37
CHROMIUM	23	88.92	99.16	99.75	100.00	2.27	96.12
COBALT	7	99.71	99.94	100.00	100.00	0.11	99.80
COPPER	20	92.28	99.39	99.80	100.00	1.70	97.14
EUROPIUM	1	99.99	99.99	99.99	99.99	.	.
GOLD	2	99.58	99.79	99.58	100.00	0.30	99.41
IRON	14	98.32	99.84	99.98	100.00	0.44	99.28
LEAD	24	34.22	92.24	98.28	99.97	15.58	66.73
MAGNESIUM	7	99.85	99.97	99.98	100.00	0.05	99.90
MANGANESE	14	99.07	99.84	99.97	100.00	0.28	99.49
MERCURY	3	-298.51	-72.06	-148.00	79.84	199.89	0.61
NICKEL	19	89.15	98.68	99.83	100.00	2.79	95.00
PHOSPHORUS	6	99.87	99.96	99.97	100.00	0.05	99.90
POTASSIUM	4	99.86	99.94	99.94	99.99	0.06	99.87
SCANDIUM	1	100.00	100.00	100.00	100.00	.	.
SELENIUM	3	99.47	99.81	99.72	100.00	0.29	99.44
SILICON	4	99.89	99.96	99.98	100.00	0.05	99.90
SILVER	11	71.44	96.81	99.38	100.00	8.44	84.85
SODIUM	5	99.55	99.80	99.82	99.92	0.15	99.61
SULFUR	6	99.00	99.50	99.59	99.80	0.36	99.04
TANTALUM	1	100.00	100.00	100.00	100.00	.	.
TIN	6	97.95	99.17	99.31	99.97	0.83	98.12
TITANIUM	7	99.80	99.96	99.99	100.00	0.07	99.87
VANADIUM	6	99.57	99.79	99.77	99.98	0.15	99.60
YTTERBIUM	1	99.90	99.90	99.90	99.90	.	.
ZINC	20	87.58	98.45	99.68	100.00	3.23	94.17

The log normal 10th percentiles of pollutant control efficiencies contained in the regulations are shown in Table 7-2. Because the studies evaluated incinerators performing in the field, the standards that were developed with these studies reflect field conditions.

For beryllium and mercury, the log normal 10th percentile values were used as the reasonable worst-case control efficiency as follows:

- Beryllium - 99%
- Mercury - 0%

7.2 SPECIALIZED EQUATIONS FOR MERCURY, BERYLLIUM, AND LEAD

7.2.1 Mercury and Beryllium

Because the limits for mercury and beryllium have already been set by the Agency as NESHAP, the allowable sludge concentration is calculated differently than those for the metals having RSD values. This alternative method eliminates the dispersion factor and the ambient air RSD value. For mercury and beryllium, equation 4 reduces to:

$$C_i = \frac{ER}{(1-CE_i) \times SF} \quad (7)$$

where: C_i = allowable sludge concentration dry basis, of sludge pollutant i (mg/kg)
ER = emission rate for pollutant i from NESHAPS (g/day)
CE_i = overall system control efficiency for pollutant i
SF = maximum sludge feed rate, dry basis (Mg/day)

Substituting the NESHAP emission rate for mercury, which is 3,200 g/24 hr, the equation becomes:

$$C_{Hg} = \frac{3{,}200}{(1-CE) \times SF} \times SF \quad (8)$$

TABLE 7-2. 10th Percentiles of Pollutant Control Efficiencies

Pollutants	Efficiency
Arsenic	0.96
Beryllium	0.99
Cadmium	0.65
Chromium	0.96
Lead	0.67
Mercury	0
Nickel	0.95

$$C_{Be} = \frac{10}{(1\text{-}CE) \times SF} \qquad (9)$$

7.2.2 Lead

For lead emissions, the RSD in equation 5 is replaced by 0.38 ug/m^3, which is 25% of the current NAAQS for lead or 1.5 ug/m^3. Equation 5 for lead reduces to:

$$C_{pb} = \frac{32{,}832}{DF \times 1\text{-}CE \times SF} \qquad (10)$$

7.3 DEMONSTRATING COMPLIANCE USING A SIMPLIFIED APPROACH

To expedite the facility-permitting process, the Agency has devised an approach that will simplify the demonstration of compliance for some facilities. The simplified analysis calculation of reasonable worst-case pollutant feed rates uses only the RSDs and control efficiencies specified by EPA and the stack height at the facility. This approach allows the facility some flexibility in how to obtain the dispersion factor (DF) and pollutant control efficiency (CE_i) values. Using this approach thus should allow a number of sludge incinerators in the United States to demonstrate compliance with the new regulations with a minimum of effort and expense.

7.3.1 Simplified Air-Modeling Procedure

A correlation has been developed between incinerator stack heights and dispersion factors calculated from the ISCLT air dispersion model. This correlation is based on the sensitivity analysis discussed in Section 4. The results of the sensitivity analysis revealed that the most significant variable that affects the dispersion of pollutants is the stack height. The other variables in the model, such as stack gas temperature, stack gas velocity, and meteorological data, have significantly less impact on the dispersion factor.

As a result of the sensitivity analysis of the ISCLT model discussed in Section 4, EPA has developed a simplified air-modeling approach using stack height as the only variable required to determine a dispersion factor. The stack height/dispersion factor relationship was developed using a series of ISCLT modeling runs performed during various stages of development of the proposed rules. The sources of the data are:

- The contractor report Sewage Sludge Incineration: ISCLT Model Sensitivity Analysis, Runs No. 25 through 33 (EPA, 1987b)
- The contractor report, Sludge Incinerator Air Quality Modeling, Sites 1 through 10 (EPA, 1986a)
- A series of runs using worst-case conditions on the Sludge Incineration Model PC ISCLT Model (EPA, 1987a)

The results of these runs are shown in Table 7-3. The dispersion factors were then graphed against the stack heights to determine the worst-case values (see Figure 7-1). The worst-case points from Figure 7-1 were then identified, as shown in Table 7-4. Next, a plot was developed that defines the worst-case conditions. The plot is shown in Figure 7-2. The worst-case dispersion factors are clearly indicated on Figure 7-2.

To calculate dispersion factors for integral stack heights between the points, linear equations were developed for each adjacent pair of points in Table 7-4. The completed table is shown in Table 7-5.

The other relevant factors needed for the simplified compliance procedure are the reasonable worst-case pollution emission control factors for each of the seven pollutants and the sludge feed rate. The emission control factors (CE_i), derived from statistical analysis of the sludge incinerator tests, are calculated as described in Section 7.1.1. Sludge feed rates are discussed in Section 9.

TABLE 7-3. Summary of Modeling Runs to Determine Worst-Case Dispersion Factors for the Simplified Air-Modeling Approach

Reference	Stack Height (m)	Dispersion Coefficient (ug/m^3/g/s)
C	7.60	56.80
B	9.20	9.08
C	11.00	50.80
C	11.00	28.70
A	11.00	54.96
A	13.00	30.03
C	13.00	47.00
A	15.00	25.18
C	15.00	24.50
B	16.20	26.70
A	17.00	28.65
C	17.00	28.10
B	18.30	12.00
A	19.00	14.56
C	19.00	14.40
B	21.80	6.87
C	22.00	1.35
C	23.00	12.00
A	23.00	11.74
B	23.30	3.69
B	27.40	4.01
C	31.00	5.14
A	31.00	4.87
B	35.40	1.70
B	39.40	7.60
B	44.00	1.35
C	47.00	1.31
A	47.00	1.37
B	55.10	5.39
A	61.00	1.12
C	61.00	1.09
C	65.00	3.99

Reference: A - EPA (U.S. Environmental Protection Agency). 1987b. Sewage sludge incineration: ISCLT model sensitivity analysis. Prepared by PEI Consulting Co. under contract 68-02-435.

B - EPA (U.S. Environmental Protection Agency). 1986a. Sludge incineration air quality modeling. Model Development and Application Division, OAR.

C - EPA (U.S. Environmental Protection Agency). 1987a. Results of sludge incineration model, PC ISCLT model. General Sciences Corporation.

FIGURE 7-1. Dispersion Factors from ISCLT Sensitivity Analysis Model Runs

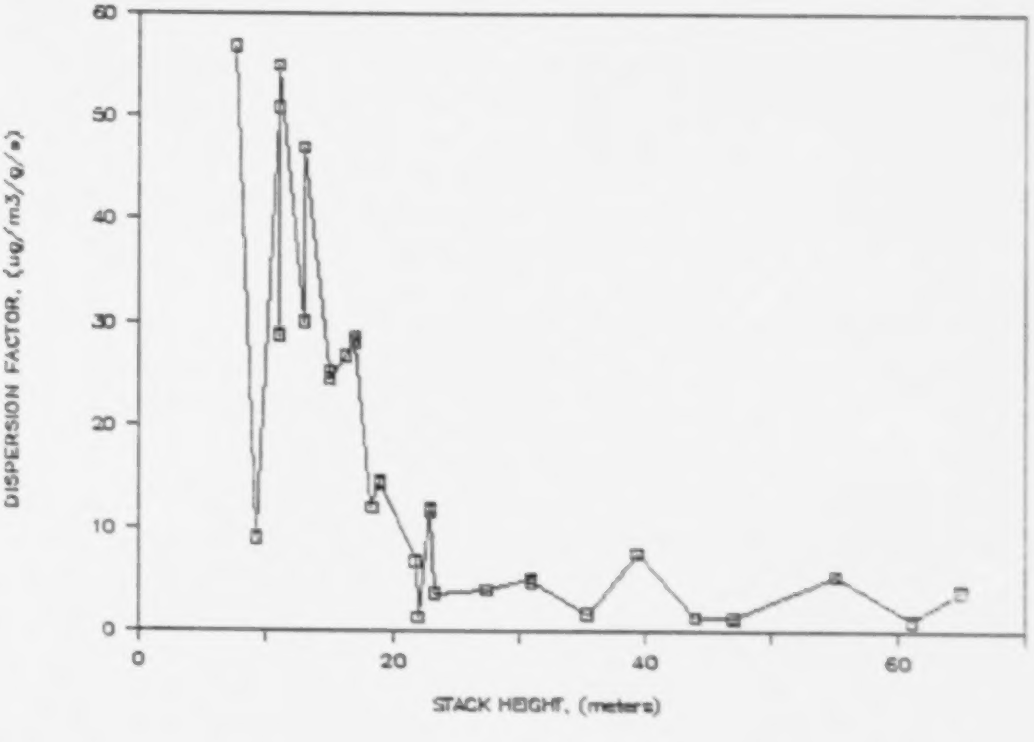


TABLE 7-4. Selected Worst-Case Dispersion Factors from Figure 7-1

Stack Height (m)	Dispersion Coefficient (ug/m^3/g/s)
7.60	56.80
11.00	50.80
13.00	47.00
17.00	28.65
23.00	12.00
39.40	7.60
55.10	5.39
65.00	3.99

FIGURE 7-2. Selected Worst-case Dispersion Factors from Table 7-4

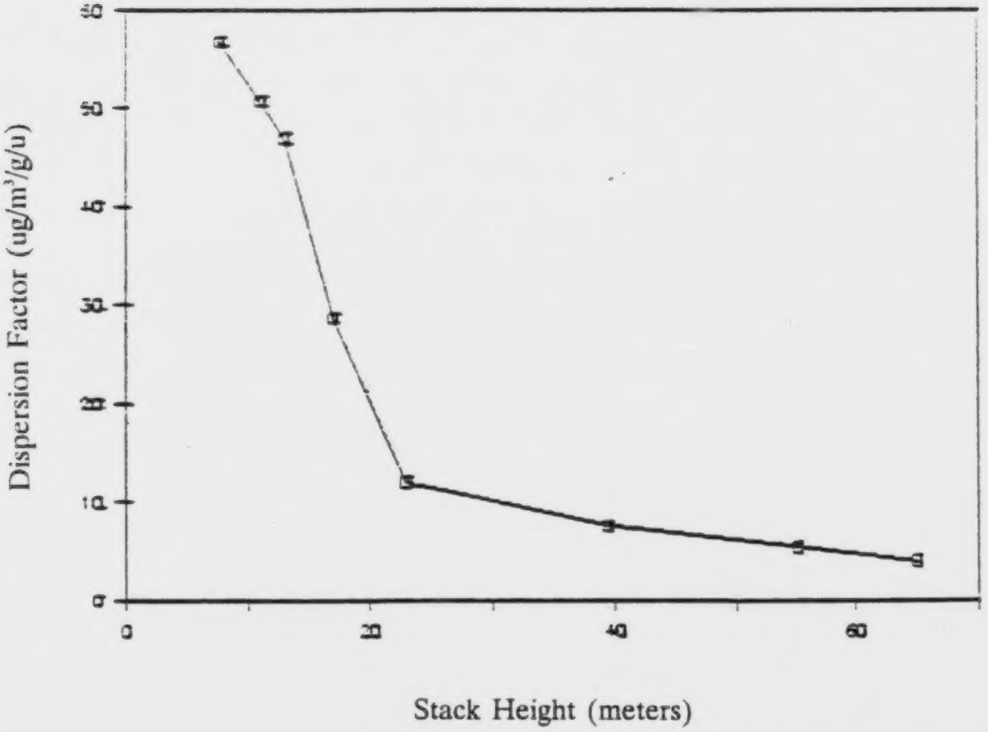


TABLE 7-5. Dispersion Factors

Stack Height (m)	Dispersion Factor (u/m^3/g/sec)	Stack Height (m)	Dispersion Factor (u/m^3/g/sec)
5	58.24	36	8.51
6	57.67	37	8.24
7	57.12	38	7.98
8	56.58	39	7.71
9	56.04	40	7.52
10	55.80	41	7.37
11	54.96	42	7.23
12	50.98	43	7.09
13	47.00	44	6.95
14	42.41	45	6.81
15	37.83	46	6.67
16	33.24	47	6.53
17	28.65	48	6.39
18	25.88	49	6.25
19	23.10	50	6.11
20	20.33	51	5.97
21	17.55	52	5.83
22	14.78	53	5.69
23	12.00	54	5.54
24	11.73	55	5.40
25	11.46	56	5.26
26	11.19	57	5.12
27	10.93	58	4.98
28	10.66	59	4.84
29	10.39	60	4.70
30	10.12	61	4.56
31	9.85	62	4.42
32	9.59	63	4.28
33	9.32	64	4.14
34	9.04	65	3.99
35	8.78		

7.4 SITE-SPECIFIC DETERMINATIONS

If a facility cannot demonstrate compliance using the simplified analysis for all of the metal pollutants, then the facility may elect to develop site-specific values for the dispersion factor and/or the metals control efficiencies.

7.4.1 Site-Specific Air Dispersion Models

A detailed air dispersion analysis may be performed to establish the site-specific dispersion characteristics and establish the relationship between stack emission rates and the maximum annual ground-level concentration around the facility. Modeling should be done in accordance with EPA's Guidelines for Air Quality Modeling (EPA, 1986c). After the air modeling is completed, the facility may recalculate the allowable pollutant feed rates (FR_i) using equation 5 and the 10th percentile control efficiencies for metals.

7.4.2 Site-Specific Control Efficiencies

The site-specific performance test requires emission testing to measure the metals control efficiencies of the incinerator system. These emissions tests must be structured to provide data for determining the extent to which the incineration system controls pollutants in the sludge. The overall incinerator and air pollution system control efficiency directly relates the pollutant level in the sludge to the emissions.

A second objective of the performance test is to obtain data on which to base the operating ranges that will be used as facility permit conditions. Making the ranges a part of permit conditions provides reasonable assurance that the incinerator will operate within the efficiency ranges. Thus adherence to the permit conditions ensures that the control efficiencies are being maintained.

These site-specific efficiencies are used in place of the reasonable worst-case control efficiencies (CE_i), which are used in the simplified calculation. Since the reasonable worst-case control efficiencies represent the lowest end of anticipated performance, actual control efficiencies measured during the test would be expected to be higher and yield a higher allowable sludge pollutant concentration.

EPA is preparing guidance for conducting sludge incineration tests. The guidance will specify sampling methods, sampling frequencies, and test methods for the metal pollutants. This guidance will be available at the time of final promulgation of these rules. All test plans for sludge incinerators that are prepared to comply with this regulation should be reviewed by a regional or state permitting official before the publication of the incinerator test guidance and before any tests are conducted.

SECTION EIGHT

REGULATION OF ORGANIC POLLUTANTS

A large body of data on the incineration of hazardous wastes has been collected in the last decade. No testing of the destruction of organics in multiple-hearth furnaces, however, has been conducted. In the initial stages of developing the sludge incinerator regulation, EPA thus had very little data on how multiple-hearth or fluidized-bed incinerators destroy organics in sludge. Previously, the Agency used rough estimates of the destruction of organics in sludge incinerators to conduct emissions estimates and calculate risk estimates.

This section discusses the tests conducted by EPA on organic emissions and how the numeric limits for THCs were developed in the proposed sludge incineration regulation.

8.1 TESTS OF THE DESTRUCTION EFFICIENCIES OF ORGANICS

To gather more information, in 1987 EPA funded extensive testing of four sludge incinerators -- three multiple-hearths and one fluidized-bed. These four incinerators were tested for both metals emissions and organic emissions. (See references 13-16 in Table 3-1.)

The tests for organic emissions were conducted to determine both how well the identified organic pollutants in the sludge feed would be destroyed and what products of incomplete combustion (PICs) would be formed. Both volatiles and semivolatiles were documented in the sludge feed, the uncontrolled incinerator exhaust, the scrubber inlet and outlet water, and the stack emissions.

A flame ionization detector (FID) was used during the tests to detect hydrocarbon emissions in the incinerator stacks. The detector is a hydrogen-oxygen flame into which a small sample of the exhaust gases from the incinerator is introduced. The FID reports the stack monitoring results as a concentration of hydrocarbons. See Section 8.2.4 for more information on the FID device.

8.1.1 Test Results and Discussion

The tests determined the sludge feed and stack emission concentrations of 21 individual compounds. A cursory inspection of the results reveals that a wide range of organic destruction efficiencies, from 99% down to large negative efficiencies, was measured (see Table 8-1).

Because of the prevalence of negative efficiencies, efficiencies drastically below the 99% range, and the wide variability of the data, no reasonable worst-case destruction efficiencies could be calculated for most of the sludge organics. The Agency, therefore, reconsidered the use of destruction efficiency estimates for organic pollutants to determine the risk of these emissions and decided that another approach was needed. Further review of the test data, summarized in Table 8-2, revealed a significant correlation between the concentration of the organic compounds detected with the FID and the concentration of the total hydrocarbons measured as part of the continuous emissions monitoring. The relationship is presented in Figure 8-1, where the total hydrocarbon concentration is plotted against the summation of concentrations of all of the volatiles and semivolatiles detected in each test run.

A regression analysis of this data revealed a correlation coefficient (R^2) of 0.72. This figure indicates that 72% of the change in the THC concentration is accounted for by the change in the summation of the volatiles and semivolatiles in the emissions. EPA has decided that this relationship is sufficiently accurate to develop a regulatory control for organic emissions.

TABLE 8-1. Organics Identified in 1987 Sludge Incinerator Testing and Their Destruction Efficiencies

	DE Range	
Compounds	High	Low
Semivolatiles		
Bis (2-ethylhexyl)phthalate	95.7	ND
1,2-Dichlorobenzene	97.3	94.2[a]
1,3-Dichlorobenzene	99.7	67.5[a]
1,4-Dichlorobenzene	95.7	87.4
2-Nitrophenol	97.2	ND
Phenol	81.7	ND
Naphthalene	90.9	ND
Volatiles		
Acrylonitrile	-1.9[a]	-349.0
Benzene	25.3[a]	-1314.0[a]
Carbon tetrachloride	99.8	79.1
Chlorobenzene	99.8	23.0
Chloroform	-39.4	-527.5
1,2-dichloroethane	97.0	ND
Trans 1,2-dichloroethene	99.4	76.0[a]
Ethylbenzene	99.3	6.0[a]
Methylene chloride	98.6	-145.0[a]
Tetrachloroethene	98.6	-175.0[a]
Toluene	99.7	-256.0[a]
1,1,1-Trichloroethane	99.6	70.0
Trichloroethene	97.9	-67.0
Vinyl chloride	-112	-426

[a] The pollutant was detected in the stack, but not in the sludge. Efficiency is calculated using the analytical detection limit of the pollutant in sludge.

[b] ND = Nondetected.

TABLE 8-2. Summary of Emissions Data from 1987 Incinerator Tests

SITE	RUN	THC (ppm)	CO (ppm)	B,2,6,PH (ug/M3)	1,2,DICHL OROBENZENE (ug/M3)	1,3,DICHL OROBENZENE (ug/M3)	1,4,DICHLORO BENZENE (ug/M3)	2-NITRO PHENOL (ug/M3)	PHENOL (ug/M3)
1	1	9	320	2.5			22		
1	2	16	450						
1	3	9	450	22.1	15.6				
1	4	7.5	360				25.9		
1	5	8	325	14.2		11.5	43.8		
2	1	21.1	821	191	34	0	50.7	89.4	173
2	2	21	821	35.8	15.8	0	24.7	42.6	107
2	3	34	1490	36.4	36.4	0	41.7	91	208
2	4		1563	15	13.5	0	16.6	0	61.7
2	5		1037	7.2	35.4	3.1	29.7	91.5	153
2	6		888	7.3	25.8	2.2	36.2	112	50.1
3	1	0.9	168	5.2	0	0	0	0	0
3	2		71	30.5	0	0	0	0	0
3	3	2	132	10.1	0	0	0	0	0
4	1		256						3.6
4	2	21.3	1503						6.9
4	3	182	1841						8.8
4	4	1.01	250						
4	5	1.72	98						
4	6	0.91	221						
4	7	12.6	1230						
4	8	12.6	1230						
4	9	28.2	2838						

TABLE 8-2. (continued)

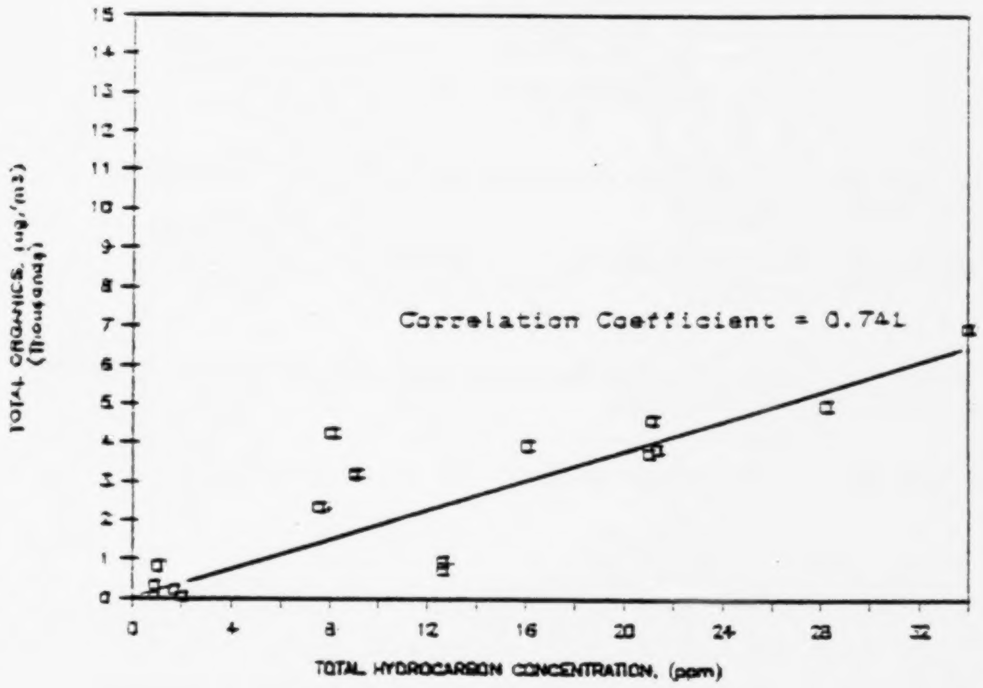
SITE	RUN	NAPHTHAL. (ug/M3)	ACRYLONITRIL (ug/M3)	BENZENE (ug/M3)	CCL4 (ug/M3)	CHLORO BENZENE (ug/M3)	CHLOROFORM (ug/M3)	1,2 DICHL OROETHANE (ug/M3)
1	1		454	883	8.1	50.7	218	0.6
1	2		884	948	5.6	75.5	214	0.2
1	3		574	774	3.1	47.6	276	0.5
1	4		439	528	3.4	27	226	0.9
1	5		1073	1287	6.8	69.4	325	4.6
2	1	65.6	2159	507	0.4	29	0.34	0
2	2	124	1892	283	0.31	18	0.38	0
2	3	85.3	3159	511	0.44	19.5	1.1	0
2	4	0	2594	573	0.46	53.8	0.49	0
2	5	282	3351	730	0.1	43.3	0	0
2	6	62.6	3869	4191	0	33.3	0	0
3	1	0	0	37	0	0.29	244	0
3	2	0	0	62	0	0.6	745	0
3	3	0	0	7.4	1.1	0	4.1	0
4	1	1.3	8737	902	0	255	0	0
4	2	3.4	2429	433	4.41	102	11.4	0
4	3	3.6	8566	2224	5.02	324	25.1	0
4	4		504	142	2.16	5.91	5.84	0
4	5		145	57.8	0.242	2.63	0.617	0
4	6		0	54.9	0.384	0	1.6	0
4	7		693	52.7	0.92	7.11	0.823	0
4	8		816	68.2	0	6.35	3.7	0
4	9		4555	307	7.18	16.3	13.1	0

TABLE 8-2. (continued)

SITE	RUN	TRANS 1,2 DICHL OROETHANE (ug/M3)	ETHYL BENZENE (ug/M3)	METHYLENE CHLORIDE (ug/M3)	TETRA CHLORO ETHENE (ug/M3)	TOLUENE (ug/M3)	1,1,1 TRICH LOROETHANE (ug/M3)	TRICHLORO ETHENE (ug/M3)	VINYL CHLORIDE (ug/M3)	DIOXIN EQUIVALENTS (ug/M3)
1	1	7.2	34.1	82.4	898	232	10.1	44.1	225	
1	2	7.3	31	108.2	962	252	14.4	81	335	
1	3	12.8	249.6	176.8	572	201	15.6	78.7	211	
1	4	11.3	37.1	154.9	450	193	25.5	46.8	175	
1	5	14	69.3	43.4	300	441	7.9	101.1	430	
2	1	0.74	10.5	0	23.6	341	0	2.8	913	
2	2	0.77	0.79	2.7	16.1	241	0	3	918	
2	3	1.1	29.8	0.14	22.4	2005	0.27	8.7	693	
2	4	0.36	91.7	323	27.9	2389	0.59	8.7	1389	
2	5	0.46	34.1	181	54.3	1322	0	4.5	1101	
2	6	0.77	11.6	29.5	114	4437	0	9.6	1273	
3	1	0	0.49	11	0	2.2	5	0.62	0	
3	2	0	0	6.9	0	2.7	2.9	0	0	
3	3	0	3.3	1.9	3.9	11.3	3.7	1.2	0	
4	1	0	579	20.1	174	744	4.62	37.3	944	
4	2	0	61.3	4.96	73.5	193	1.66	7.19	511	
4	3	0	444	33.5	350	1316	24.4	141	465	
4	4	0	27.4	2.73	0.263	136	1.33	0.836	0	0.983
4	5	0	3.84	0	0.174	25.2	1.13	0.191	0	1.214
4	6	0	5.83	0	0.503	31.9	0.39	0.377	0	0.995
4	7	0	0	1	6.59	2.38	2.96	9.45	0	0.271
4	8	0	0	5.32	11.1	1.54	9.94	9.21	0	1.148
4	9	0	0	0.44	7.6	29.5	5.44	1.87	20.1	

NOTE: DIOXIN SAMPLES TAKEN AFTER THE AFTERBURNER

FIGURE 8-1. Total Hydrocarbon Concentration (THC) vs. Total Organics Concentration of Volatiles and Semivolitiles Detected in Test Run



based on monitoring of the concentration of THCs in incinerator stack emissions.

8.2 DETERMINATION OF ALLOWABLE STACK EMISSION RATES FOR THC

Similar to the numeric limits for metals, the THC allowable stack concentration is based on a human risk factor and air model dispersion factors. Instead of applying control efficiencies, to relate THCs to sludge concentration, however, the volume of gases in the stack and the instrument monitoring data are used to determine if the incinerator is meeting the human health criteria.

The variables in the THC calculation include:

- An RSD, which includes a cancer potency value (q_1*) for THC and a 1 x 10^{-5} MEI risk level
- The dispersion factor (DF) for the incinerator
- The volume of gases in the stack
- Correction factors for the FID measurement device which continuously monitors THCs in the stack

See Section 6 for a discussion of the RSD and cancer potency calculations.

8.2.1 THC Dispersion Factor

The stack concentration of THC is determined for each site using the site-specific dispersion factors obtained from either Table 7.5 or a site-specific air modeling computer run. Table 7.5 is based on a series of worst-case air dispersion model calculations as explained in Section 7, which relates the MEI dispersion factor to the incinerator stack height. If a dispersion factor of

10 ug/m^3 $(g/sec)^{-1}$ is used, for example, the allowable stack emission rate would be:

$$\text{Emission rate g/s} = \frac{\text{RSD } (ug/m^3)}{\text{DF } (ug/m^3)(g/sec)^{-1}} \qquad (11)$$

$$\text{or:} \qquad 0.27 \text{ g/s} = \frac{2.69 \text{ } ug/m^3}{10(ug/m^3)(g/sec)^{-1}}$$

8.2.2 Combustion Gas Flow

Because the measuring instrument (FID) for THC reports THC emissions in terms of gas concentration (parts per million, volume) (ppmv), it is necessary to convert the allowable emission rate, calculated in g/sec to a corresponding concentration in ppmv. To make the conversion, the total gas flow in the incinerator stack must be known. The total gas flow can be determined either by direct measurement or by using standard sludge combustion calculations.

The equation for the estimated gas flow rate (gram moles/day) used to calculate the allowable stack THC concentration is based on standard combustion parameters, information on the sludge being burned, and the amount of auxiliary fuel used. The sludge parameters include dry feed rate, the percentage of combustibles in the sludge, and the heating value of the sludge combustibles. By combining all of the factors, an estimate of the total gas flow on a dry basis at 7% oxygen can be developed.

To calculate a maximum combustion gas flow rate, several components of the combustion gas stream exiting an incinerator must be identified:

- CO_2 and H_2O from combustion of the sludge volatiles
- H_2O contained in the incoming sludge not formed during the combustion process (free-moisture)

- N_2 from the stoichiometric air used in combustion of the sludge volatiles
- N_2 and O_2 passing through the system as excess air that is not required for the combustion reaction
- CO_2 and H_2O from auxiliary fuel combustion
- N_2 from the stoichiometric air used to burn the auxiliary fuel
- N_2 and O_2 from excess air used for the fuel combustion

To calculate these combustion gas components in terms of gram moles/day, as presented in Appendix E of the proposed regulation, the following information is needed:

- Sludge feed rate, Mg/day
- Sludge percent moisture, %, which indicates percentage of solids
- Sludge percent volatiles, %
- Heating value of the sludge volatiles, kcal/g
- Oxygen concentration in the exit gases, %
- Auxiliary fuel type (e.g. natural gas, fuel oil)
- Auxiliary fuel use rate, ft^3 or lb/day
- Excess air firing rate for fuel burners, %

8.2.2.1 Derivation of the Combustion Gas Flow for the THC Standard

To standardize the THC measurement and eliminate two major variables in the total molar gas flow rate calculation, both the total gas flow rate and the actual FID measurement are corrected to 7% oxygen (50% excess air), and a moisture-free basis. By correcting to 7% oxygen, the effect of varying excess air rates can be eliminated in the measurement of the THC concentration. In a similar manner, the effect of variable sludge percent moisture can be eliminated.

From the list above, the remaining incinerator variables necessary to predict combustion gas flow on a molar basis are:

- Sludge feed rate
- Sludge percent volatiles
- Heating value of the sludge volatiles
- Auxiliary fuel type
- Auxiliary fuel usage

To further simplify the gas calculation procedure, the following assumptions, based on the owner/operator's experience, are made:

- The percentage of volatiles in a facility's sludge does not change significantly over time
- The heating value of the sludge volatiles does not change significantly over time
- 7.5 lb of stoichiometric air is required for each 10,000 Btu of heating value of both sludge volatiles and auxiliary fuel (1,350 g air)/(1,000 kcal) (EPA, 1979)
- 0.5 lb of water is formed for each 10,000 Btu of heating value of both sludge volatiles and auxiliary fuel (90 g/H_2O)/(1,000 kcal) (EPA, 1979)
- Dry air and dry combustion gases are treated as having equal molecular weights (EPA, 1979)

When all the above assumptions are used, the calculation of the molar quantities of combustion gases is considerably simplified. The complete derivation of the calculation contained in Appendix E of the proposed regulation is given below.

Step 1: Calculate the CO_2 and H_2O Formed from the Sludge

Because the THC is determined on a dry basis, determining the water generated is not necessary.

Combustion Gases from Sludge

This equation calculates the gram moles of dry combustion gases evolved at 7% oxygen (50% excess air).

$$\begin{aligned} \text{SCF} = {} & \text{SF (Mg/day)} \times \text{VF (\%)} \times \text{VEHC (kcal/g)} \\ & \times \text{(1,348 g/air)/1,000 kcal} \times 1 \times 10^{6} \text{ g/Mg} \\ & \times 1.50 \text{ (excess air)} \times \text{(1 g-mole air)/28.84 g air} \end{aligned} \tag{12}$$

where SCF - maximum combustion gas flow rate from sludge combustion, g-moles/day
SF - maximum daily sludge feed rate, metric tons per day (megagrams) (dry basis)
VF - average volatile fraction of the sludge solids
VEHC - average heating value of the volatile fraction of the sewage sludge, kcal/g

The equation can be simplified to combine all the constant terms to yield:

$$\text{SCF} = \text{SF} \times \text{VF} \times \text{VEHC} \times 7.011 \times 10^{4} \tag{13}$$

Step 2: Combustion Gases from Auxiliary Fuel

The following three equations are the basis of Section 2 of Appendix E of the proposed regulation.

Natural Gas

For natural gas, the equation for the gram moles dry combustion gas is:

$$FGF = FR_{Ng} \times 1{,}000 \text{ Btu/ft}^3 \times (7.5 \text{ lb air})/10{,}000 \text{ Btu} \qquad (14)$$

$$\times\ 1.50 \times (1 \text{ g-mole air})/28.84 \text{ g air}$$

$$\times\ (453.6 \text{ g-mole})/\text{lb-mole}$$

where FGF - fuel gas flow rate of combustion gases, g-moles/day

FR_{Ng} - daily fuel use based on annual usage, ft^3 per day

1,000 Btu/ft^3 - average heating value of natural gas

$\frac{7.5 \text{ lb/air}}{10{,}000 \text{ Btu}}$ - stoichiometric air requirement for combustion of gas

1.50 - 50% excess air rate

28.84 - molecular weight of air

453.6 - conversion from lb-moles gas to g-moles gas

This equation can be reduced to the form:

$$FGF = FR_{Ng} \times 17.69 \qquad (15)$$

Number 2 Fuel Oil

For #2 fuel oil, the equation is:

$$FGF = FR \times 18{,}300 \text{ Btu/lb} \times 7.5/10{,}000 \text{ lb} \times 1.50$$

$$\times\ 1 \text{ g-mole air}/28.84 \text{ g air} \times 453.6 \text{ g-mole/lb-mole} \qquad (16)$$

The elements of this equation are identical to those in equation 15 except:

$FR_{\#2\ oil}$ - daily fuel use based on annual use in lb/day

18,300 - average heating value of #2 fuel oil Btu/lb

Equation 16 for #2 fuel oil similarly reduces to

$$FGF = FR_{\#2\ oil} \times 323.80 \qquad (17)$$

Number 6 Fuel Oil

For #6 fuel oil, the equation is:

$$FGF = FR_{\#6\ oil} \times 17{,}500 \times 7.5/10{,}000 \times 1.50 \quad (18)$$

$$\times\ 1\ \text{g-mole air}/28.84\ \text{g air} \times 453.6\ \text{g-mole/lb-mole}$$

The elements are identical to those in equation 16 except:

17,500 - average heating value of #6 fuel, Btu/lb

The equation reduces to:

$$FGF = FR_{\#6\ oil} \times 309.65 \quad (19)$$

8.2.2.2 Oxygen Correction Factor

The THC measurement obtained from the combustion gases leaving a sewage sludge incinerator requires the application of a correction factor to calculate the actual excess air present in the combustion gases. If the THC measurement was not corrected to 7% oxygen or some other standard, facilities could lower the THC concentration detected without reducing the actual emission rate of THC simply by adding higher rates of air to the incinerator. High excess air rates "dilute" the THC concentration detected by the FID instrument and could allow an incinerator to appear to be meeting the THC standard, when actually the THC emissions are in excess of those set by the RSD calculation. The correction factor for oxygen is as follows:

$$THC_{actual} = THC_{measure} \times 14/21\text{-}y \quad (20)$$

where y - the actual oxygen concentration, %

A facility can easily apply the oxygen correction factor, because continuous oxygen monitoring is also being proposed in this rule as §503.62(g).

8.2.3 FID Measurement of THC Concentration

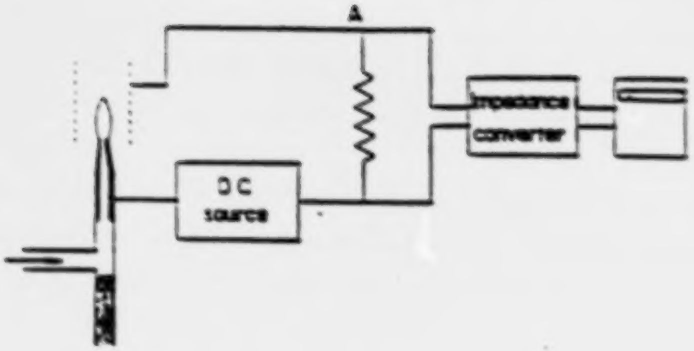
The flame ionization detector detects hydrocarbon emissions in the stack of an incinerator. It reports the stack monitoring results as a concentration of hydrocarbons. The instrument reads out in parts per million of THC by volume. Thus the stack emission rate in grams per second must be converted to a stack concentration in parts per million, as explained earlier.

The FID is a hydrogen-oxygen flame into which a small sample of exhaust gases from an incinerator is introduced. If any gases are present in the sample, they will be burned in the flame (see Figure 8-2).

When any carbon-carbon (C-C) or carbon-hydrogen (C-H) bonds are broken and oxidized in the flame, an ion is released and an electrical detection system senses the release of the ion. The electrical signal strength is thus a direct measure of the number of C-C and C-H bonds being oxidized in the flame. By using a series of calibration gases of known hydrocarbon concentration that are periodically introduced into the sample stream, the direct readout of this signal can be calibrated to indicate the concentration of hydrocarbons in the sample stream.

An FID detector that determines the THCs in a stack can also be viewed as an auxiliary incinerator (afterburner). If there is little or nothing in the sampled gas from the incinerator (typically less than 10 ppm) to burn in the detector, the incinerator has done a good job of destroying the organics. A high level (greater than 10 ppm) indicates the incinerator is operating inefficiently.

FIGURE 8-2. Basic Circuit of the Flame Ionization Detector


A
Impedance converter
DC source

Note: If hydrogen is not used as the carrier gas, it may be introduced through a tube (see arrow).

One problem in interpreting the FID response to an organic compound is that the FID only measures and "counts" the number of chemical bonds being broken. Thus a molecule with a total of 12 C-C and C-H bonds, for example, will respond differently from a molecule that contains 16 C-C and C-H bonds. A given mass of benzene, in other words, will respond differently from the same mass of 2,3,7,8-TCPD (tetrachlorinated paradioxin). The FID therefore provides no direct information about the chemical nature of the molecule being burned; rather, it provides information only about the number of the bonds.

The differing FID responses to organic compounds is expressed as a series of response factors. Output from a detector is typically expressed as an equivalent ppm of a calibration gas -- usually methane or propane -- and the response factor is referenced to a particular gas equivalent. As an example, published response factors range from 10% for carbon tetrachloride to 225% for acetylene when referenced to methane, set at 100%. Thus carbon tetrachloride provides a response ten times less than methane, and acetylene produces a response over two times as much as methane.

To account for this varying response by the FID, the Agency has calculated a weighted-average response factor similar to the way the cancer potency weighted average q_1* was developed for THCs (see Section 6.4.1). This factor is used to correct the reading from the FID to account for the same mix of organics used to determine the q_1*.

8.2.4 Conversion of the THC RSD to a Site-Specific Stack Concentration

The RSD value for the MEI is converted into a site-specific stack concentration using the following equation:

$$SC_{THC} = \frac{RSD \times 86{,}400 \times 0.75 \times 1.7 \times 1 \times 10^{6}}{DF \times CGF \times 34.0} \qquad (21)$$

or:

$$SC_{THC} = \frac{RSD \times 3{,}240{,}000{,}000}{DF \times CGF \times 34.0}$$

where SC_{THC} - site-specific THC concentration limit in the stack, ppm (vol)
RSD - risk-specific dose for THC, ug/m^3.
86,400 - conversion from seconds to days, 86,400 sec/day
0.75 - factor to adjust for the estimated loss of heavy organics in the sampling system (dimensionless) (see Appendix D)
1.7 - ratio of the FID response factor of propane (3.0) to the weighted average FID response of the list of compounds (1.8) used to determine the weighted average unit risk (see Appendix D)
1×10^{6} - conversion of concentration to ppm
DF - dispersion factor, ug/m^3 (g/sec)$^{-1}$
CGF - flow of combustion gases from the incinerator, g-moles/day
34.0 - weighted average molecular weight of the THC compounds used to develop the q_1*, g-moles

This equation calculates the allowable concentration of THC in the emissions from a specific incinerator in parts per million on a molar basis. The concentration expressed in gram moles per gram mole is quantitatively the same as the concentration expressed on a volume per volume basis for a gas mixture. Thus, the above equation yields the maximum allowable THC concentration directly as a volumetric concentration.

Combining all the constants yields:

$$\frac{86{,}400 \times 0.75 \times 1.7 \times 1 \times 10^{6}}{34} = 3.24 \times 10^{9}$$

SECTION NINE

INCINERATOR MANAGEMENT PRACTICES

The operation of a sewage sludge incinerator involves the interrelation of a number of operating variables that must be controlled to ensure satisfactory operation and adequate control of air emissions. The major operating variables for sludge incinerators are:

- Combustion and operating temperatures
- Excess air rate
- Sludge quality and feed rate
- Air pollution control system operating parameters

Each of these variables can have a profound impact on the quantities and quality of emissions from sludge incinerators. Thus EPA is proposing selective controls for these operating variables that are known to affect emissions.

The most direct procedure for selecting appropriate limitations for each relevant variable is to test incinerator systems and characterize the acceptability of emissions. The ranges of the operating parameters observed during the tests can then be used to set limits. No testing, however, is performed on sludge incinerators that can demonstrate compliance with the sludge pollutant concentrations when using the reasonable worst-case pollutant control efficiencies for metals developed in Section 7. Limitations on operating parameters, therefore, cannot be obtained from a test burn.

To have some degree of assurance that untested incinerators will maintain a reasonable degree of control, EPA is proposing to include limitations on maximum combustion temperature, maximum excess air rate, and air pollution control system parameters. Each of these limitations is discussed below.

9.1 TEMPERATURE LIMITATIONS

Temperatures in incinerators affect the emissions of both organic compounds and metals. In developing a proposal for incinerator temperatures, both high and low temperature limits were considered. Combustion temperatures that are too low cause incomplete combustion and destruction of organic compounds in sludge as well as promote the formation of products of incomplete combustion (PICs). These incompletely destroyed compounds and PICs are emitted with the combustion gases. Temperatures that are too high increase the volatilization of the metal pollutants from the sludge solids and increase their emission. Excessively high temperatures also damage equipment and result in increased maintenance costs.

9.1.1 Minimum Temperature

The rationale for maintaining a minimum temperature in an incinerator is to ensure that the organic compounds in the sludge are adequately burned. The establishment of a continuous THC monitoring limit for all incinerators (including those not tested for metals emissions), however, eliminates the need to establish a minimum temperature limit.

An adequate minimum temperature can be maintained by monitoring the concentration of organic compounds in the incinerator emissions continuously, and by requiring the operator to maintain the effluent concentration at or below a risk-based limit. In effect, the incinerator is undergoing a continuous emission test for organic destruction using THC as a measure of the organic destruction and, thus, no lower combustion temperature is required in the facilities permit.

9.1.2 Maximum Temperature

A maximum combustion temperature limit for untested incinerators is needed to avoid excessive metal emissions. The metal pollutants arsenic, cadmium, and lead tend toward high emission rates under high combustion temperatures. A regression analysis of metals' control efficiencies and combustion zone operating temperatures was conducted using the control efficiency database (EPA, 1988a) (see Appendix F). The results are shown in Figures 9-1, 9-2, and 9-3 for arsenic, cadmium, and lead, respectively. To determine the combustion zone temperature that corresponds to the 10th percentile control efficiencies, the 10th percentile control efficiencies for arsenic, cadmium, and lead were substituted into the regression equations represented by the least squares fit shown in Figures 9-1, 9-2, and 9-3. An example of this procedure is given using the analysis for arsenic.

The straight line regression equation for arsenic, shown in Figure 9-1, is in the following form:

$$\log(\%\ \text{mass emitted}) = \text{intercept} + (\text{slope} \times \text{temperature}\ [T]) \qquad (22)$$

From Appendix F, page 1, the intercept is -7.109 and the slope or temperature coefficient is 0.00847. Substituting into the equation above:

$$\log(\%\ \text{mass emitted}) = -7.109 + 0.00847\ T$$

Since the 10th percentile control efficiency for arsenic is 96.0% (see Table 7-2), the percent emitted is (100 - 96.0 = 4.0). Substituting in the equation above:

$$\log 4.0 = -7.109 + 0.00847\ T$$

FIGURE 9-1. Regression Analysis of Percent Arsenic Emitted Versus Incinerator Combustion Temperatures

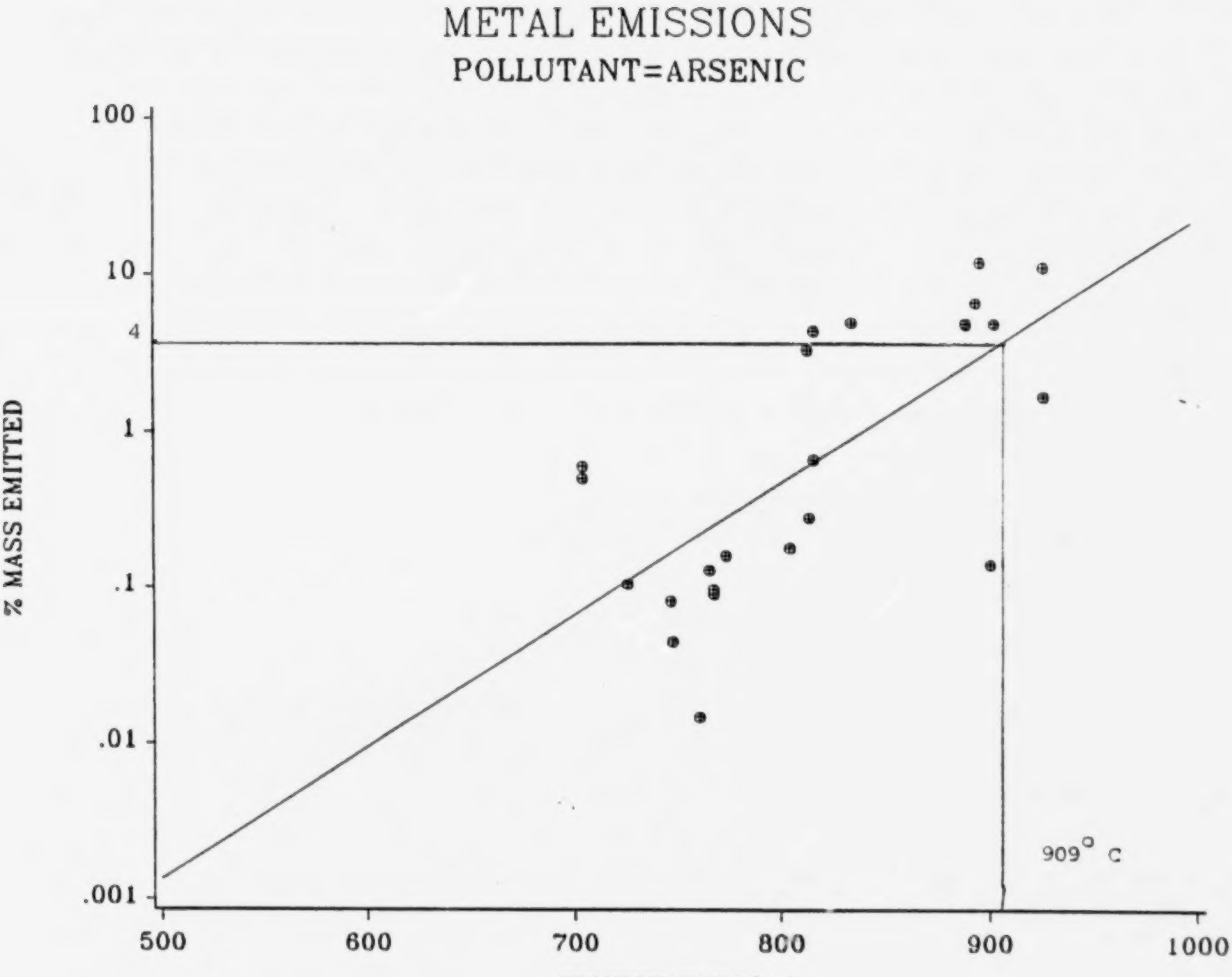


FIGURE 9-2. Regression Analysis of Percent Cadmium Emitted Versus Incineration Combustion Temperature

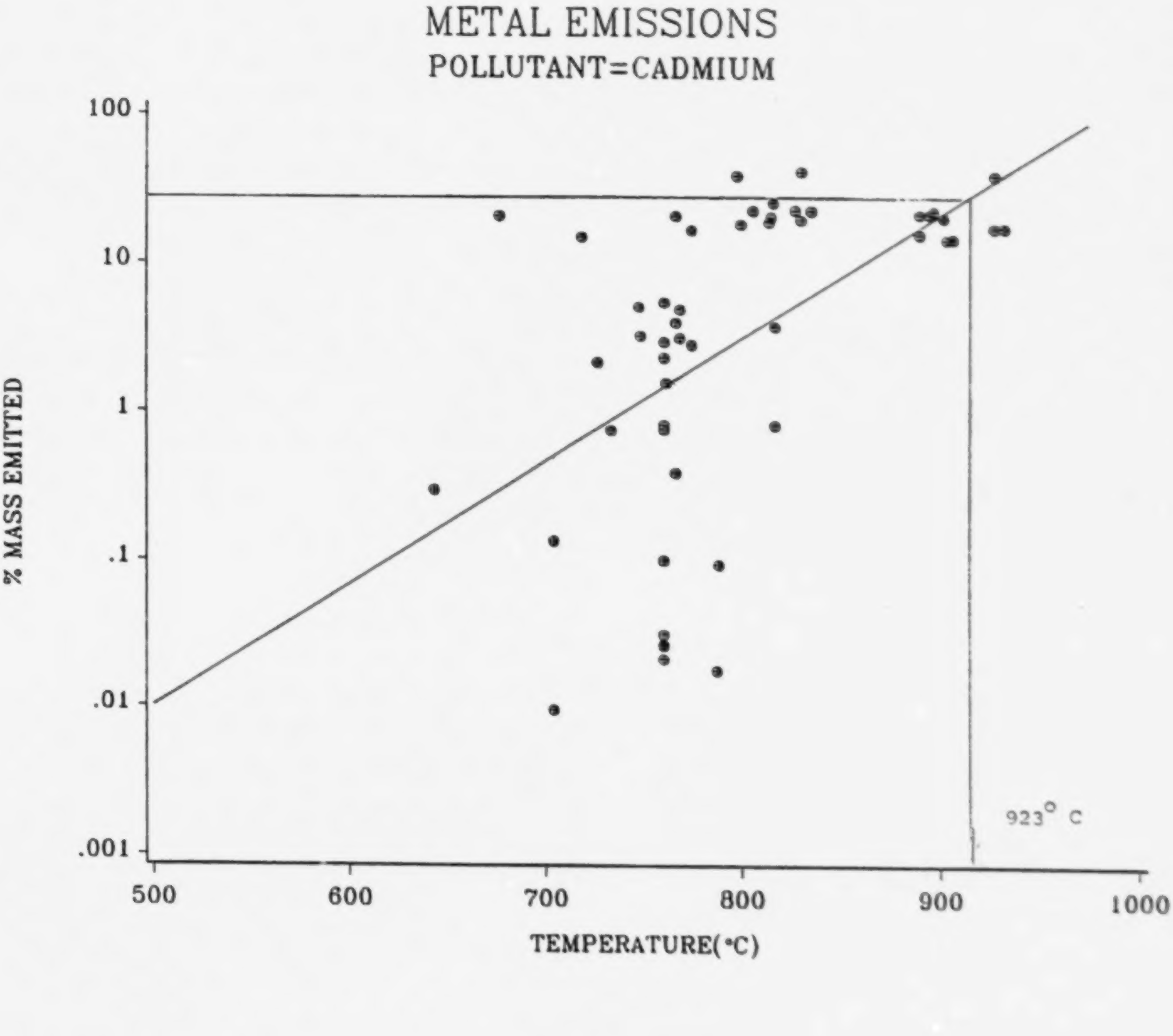
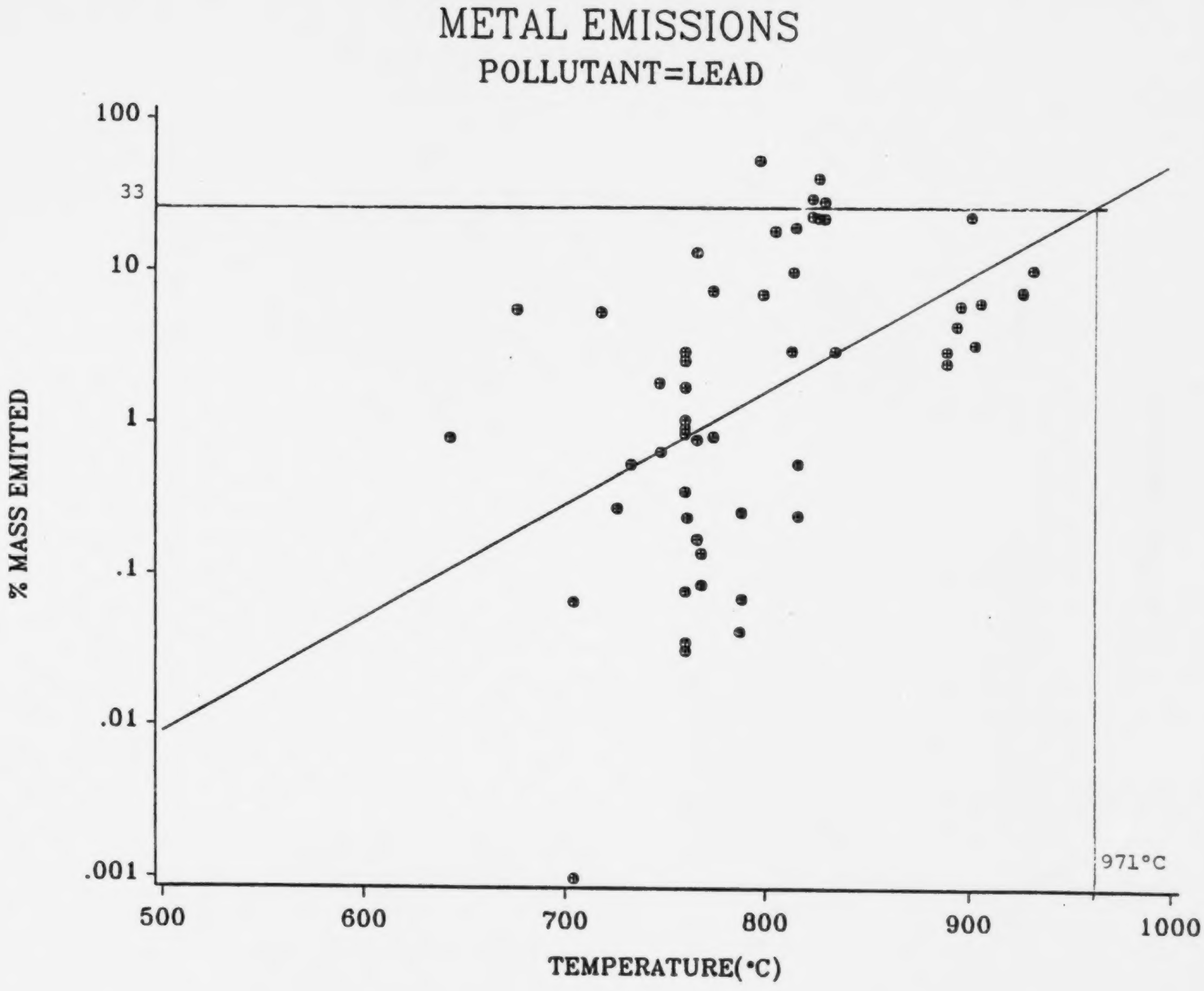


FIGURE 9-3. Regression Analysis of Percent Lead Emitted Versus Incinerator Combustion Temperature



solving for T:

$$T = 909°C \text{ or } 1{,}669°F$$

In a similar manner, the 10th percentile temperature for cadmium is 923°C (1,695°F) and for lead is 970°C (1,780°F).

Based on the above data, EPA has determined that combustion temperatures in sludge incinerators should be maintained below 1,700°F to ensure that the 10th percentile emission control efficiencies are not violated by untested incinerators. The Agency has proposed as a management practice a maximum combustion temperature of 1,650°F, reached by subtracting a 50°F margin of safety from the 1,700°F upper limit.

9.2 EXCESS AIR RATE

The excess air rate in a sewage sludge incinerator has a direct effect on the level of metals emissions. A high excess air rate, measured as a high percentage of oxygen in the combustion gases, indicates that more air is being introduced into the combustion zone than is needed to achieve complete combustion. This extra air increases the volume of combustion gases passing through the combustion zone, which increases the velocity of combustion gases in contact with burning sludge. The higher gas velocity tends to carry larger quantities of partially burned sludge particles and ash particles out of the incinerator and into the air pollution control system. The higher loading of both the combustion gases and the sludge and ash particles results in greater atmospheric emissions.

9.2.1 Minimum Excess Air Rate

An excess air rate that is too low can result in inadequate combustion of the sludge organic constituents due to insufficient oxygen in parts of the combustion zone. Continuously monitoring THCs in the stack and limiting the THC concentration to a risk level of 1×10^{-5}, however, precludes the need to specify a minimum excess air level to ensure complete combustion. If a sludge incinerator is operated at an excess air level too low to obtain good combustion, then the THC concentration will exceed the 1×10^{-5} limit and the operator will be forced to increase the excess air to bring the THC level down to the limit specified in the permit.

9.2.2 Maximum Excess Air Rate

9.2.2.1 Multiple-Hearth Incinerators

Data allowing EPA to determine a maximum excess air rate in multiple-hearth incinerators are limited. An evaluation of the results from the 1987 emissions testing of three multiple-hearth sewage sludge incinerators indicates that the control efficiencies for lead emissions drop as the excess air rate, expressed as percent oxygen, increases (see Table 9-1). The statistical fit using the least squares regression analysis of the lead control efficiency versus excess air rate is plotted in Figure 9-4. The correlation coefficient for the regression calculation is 0.609.

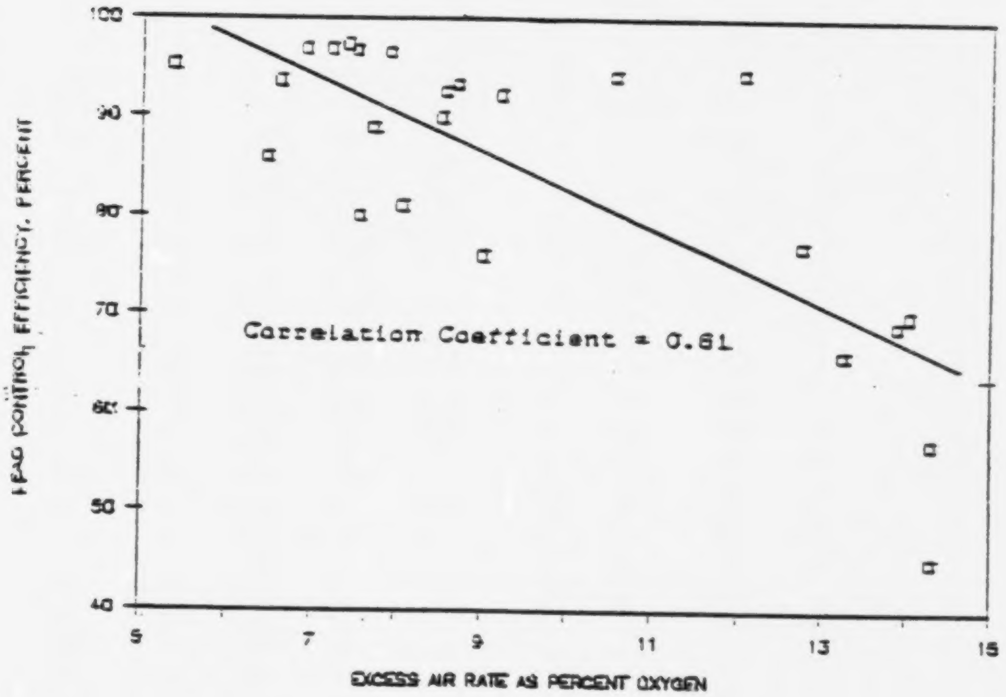
Given the regression plot and the 10th percentile value for lead, 67% (from Table 10 in Appendix E), the corresponding percent oxygen value is 13.9%. Using this relationship and allowing for a margin of safety, EPA has determined that a maximum oxygen concentration of 12% should be the upper limit for excess air in multiple-hearth incinerators that are not subject to testing.

TABLE 9-1. Metals Control Efficiencies for Four Sludge Incinerators Tested in 1987

SITE	FURNACE TYPE	SAMPLE RUN	ARSENIC (%)	BERYLLIUM (%)	CADMIUM (%)	CHROMIUM (%)	LEAD (%)	NICKEL (%)	MAXIMUM TEMP, F	EXIT TEMP, F	PERCENT OXYGEN
1	MH	S01	95.5	ND	77.0	99.4	70.0	98.1	1520	765	14.1
1	MH	S02	96.9	ND	80.0	99.9	67.0	98.7	1520	765	NR
1	MH	S04	97.3	ND	78.0	98.8	66.0	32.6	1520	750	13.3
1	MH	S05	97.4	ND	82.0	99.8	77.0	96.7	1510	750	12.8
1	MH	L01	94.3	ND	68.0	99.7	69.0	98.9	1520	690	13.9
1	MH	L02	94.1	ND	77.0	99.9	57.0	97.8	1520	760	14.3
1	MH	L03	93.4	ND	67.0	99.8	45.0	ND	1490	810	14.3
2	MH	S01	96.4	ND	85.0	99.6	96.5	99.6	1730	815	7.9
2	MH	S02	96.8	ND	84.0	97.4	96.8	99.5	1690	805	7.5
2	MH	S03	94.9	ND	77.0	98.0	97.4	98.7	1535	850	7.4
2	MH	S04	98.9	ND	76.0	99.4	96.9	98.7	1535	850	7.2
2	MH	L01	88.0	ND	77.0	99.6	93.7	98.3	1590	900	6.6
2	MH	L02	96.6	ND	81.0	99.7	96.9	99.7	1455	980	6.9
2	MH	L03	93.2	99.8	78.0	98.9	95.3	96.4	1660	930	5.4
3	FB	S01	99.9	ND	95.9	99.7	98.3	99.4	1315	1410	11.4
3	FB	S02	99.9	ND	96.8	99.7	99.9	99.5	1314	1433	9.6
3	FB	S03	99.9	ND	95.0	99.8	99.9	99.6	1297	1415	NR
4	MH	S01	ND	ND	79.0	NR	94.3	99.8	1265	800	10.6
4	MH	S02	ND	ND	81.0	NR	92.6	99.8	1480	1060	8.6
4	MH	S03	ND	ND	85.0	NR	94.5	99.9	1325	1055	12.1
4	MH	S04	99.8	ND	77.0	NR	81.0	99.9	1450	935	8.1
4	MH	S05	ND	ND	74.0	NR	80.0	99.8	1540	910	7.6
4	MH	S06	ND	ND	85.0	NR	93.4	99.5	1620	850	8.7
4	MH	S07	99.9	ND	79.0	NR	76.0	99.8	1640	845	9.0
4	MH	S08	ND	ND	83.0	NR	92.3	99.9	1435	870	9.2
4	MH	S09	99.7	ND	79.0	NR	90.0	99.9	1455	955	8.5
4	MH	S10	ND	ND	78.0	NR	86.0	99.9	1440	910	6.5
4	MH	S11	ND	ND	82.0	NR	89.0	99.9	1720	915	7.7

MH = MULTIPLE HEARTH FURNACE
FB = FLUIDIZED BED FURNACE
ND = NOT DETECTED
NR = NOT REPORTED

FIGURE 9-4. Lead Control Efficiency vs. Excess Air Rate



9.2.2.2 Fluidized-Bed Incinerators, Electric Furnaces, and Rotary Kilns

Comparable data on the effect of emissions rates with high excess air rates are not available for fluidized-bed or electric sludge furnaces. Several references, however, provide guidance on how to set upper limits on excess air rates for these two furnace types. EPA's draft Guidance for Writing Case-by-Case Permit Requirements for Municipal Sewage Sludge (1988b) recommends excess air rates of 20-45% for fluidized-bed furnaces and 29-70% for electric furnaces. EPA's Process Design Manual for Sludge Treatment and Disposal (1979) recommends 20-45% for fluidized-bed units and 20-70% for electric units.

The Water Pollution Control Federation's Incineration Manual of Practice (1988) recommends a maximum 40% excess air rate for fluidized-beds and a range of 20-30% for electric furnaces. Based on these references and on discussions with experts on sludge incineration, EPA is proposing to limit excess air in fluidized-bed furnaces to a maximum of 50%, or 7% oxygen (Brunner, 1988). For electric furnaces, EPA is proposing to limit excess air rates to 70% excess air, or 9% oxygen.

No literature references were found on recommended excess air rates for rotary kiln incinerators that burn sewage sludge. EPA is therefore proposing to use the same excess air rate as that proposed for multiple-hearth units 1/m, namely 12% oxygen, or 133% excess air. Rotary kiln incinerators typically require fairly high excess air rates (50-150%); where data are lacking, therefore, the multiple-hearth limitation seems appropriate.

9.3 SLUDGE FEED RATE

Sludge incinerators are built to operate continuously, but a rapid change in the quantity or quality of sludge entering the incinerator can cause dramatic changes in furnace operation. As a result, the concentration of the pollutant in the ambient air around the facility can exceed the RSD.

Under steady-state conditions, the burning sludge supplies most of the heat required to drive off the large quantities of water that enter with the sludge solids and to initiate burning of the new sludge. If the volume of the sludge being burned is held constant, the excess air rate can be optimized and the heat lost to excess air can be reduced. In the case of multiple-hearths, ash is not rabbled out of the incinerator until it has cooled and given up its heat to entering combustion air. These optimum conditions are nearly impossible to achieve unless the sludge feed is consistent.

Feed changes also affect air pollution control systems, which operate within specific design parameters. When the sludge feed varies, the incinerator off-gases will also vary in quantity and temperature. This variability can decrease the efficiency of the air pollution control equipment. The sludge feed rate, therefore, must be monitored to provide information to the operator on the quantities of sludge being fed to the incinerator(s). Monitoring the sludge feed rate ensures that it does not exceed the maximum dry sludge feed rate used to establish the maximum acceptable sludge concentration of the metal pollutants.

Measuring Sludge Feed Rate

Load cell conveyor belt scales are widely used to measure the incinerator sludge feed rate. The weight of sludge on the belt is measured by strain gauges. As the weight on the belt increases, the stress on the load cell increases, which causes a corresponding change in the electrical resistance of the strain gauge. The electrical resistance, combined with the speed of the belt, is fed to a microprocessor that calculates the mass per unit time of sludge on the belt.

9.4 AIR POLLUTION CONTROL SYSTEMS

To ensure that the air pollution control (APC) system is functioning properly and that there are no excess pollutant emissions, some limits on the operating conditions of the APC system must be imposed. Although historically wet scrubber systems have met particulate emission standards, little evidence exists to indicate whether current wet scrubbers can effectively control organic emissions from incinerators. Also, if a wet venturi scrubber is operated at an excessively low pressure drop, particulate removal efficiency will be reduced and excessive particulate matter will be emitted. Because most of the metals emitted from sludge incinerators are in the solid particulate phase, a low pressure drop will lead to excessive metals emissions.

Other types of air pollution control systems can control sludge incinerator metal emissions more efficiently than wet scrubbers. Systems such as fabric filters (baghouses), wet and dry electrostatic precipitators, and semidry and dry scrubbing systems may be required on some incinerators to meet the emission levels proposed in the standards. Fired afterburners may also be required on some MHF to meet the requirements of the regulation.

Due to the potential variety of air pollution control devices, EPA has required the permit writer to determine the operating parameters of the APC devices that should be specified in the facilities permit and the numerical limitations of these parameters. When emissions testing is conducted to establish an acceptable control efficiency for metals emissions, the test report will provide the basis for setting APC operating conditions.

9.4.1 Wet Scrubbers

EPA has identified nine different designs and configurations of wet scrubbing systems on sludge incinerators, ranging from simple spray chambers to high-pressure drop venturi-tray scrubber combinations. EPA's analysis of wet scrubbing systems indicates that a number of current sewage sludge incinerators that burn sludges with high concentrations of organics or metals will not be able to meet the standards proposed in these regulations without improving the organic and metals removal efficiencies of their air pollution control systems.

A major problem with wet scrubbing systems is the decrease in efficiency of particulate removal as particle size decreases. Wet scrubbers suffer a marked decrease of removal efficiency as the average particle size drops below 1 u. Tests of sludge incinerators indicate that metals emissions are associated with the smaller particle size. Thus wet scrubbers may not achieve high collection efficiencies for many metals (Farrell and Wall, 1981).

EPA initiated a study as a part of the review process for the New Source Performance Standards (NSPS) for sludge incinerators to determine if the pressure drop of the current wet scrubber systems could be correlated with particulate emissions. For this study, detailed data were collected on 60 sludge incinerators (Crowder, 1988). No quantitative correlation between particulate emission rates and scrubber pressure drops was identified. Regardless, emissions are commonly known to increase as the pressure drop decreases for a given incinerator and a given scrubber. Therefore, at any given plant, proper operation and maintenance of emission control devices is a key factor in minimizing particulate emissions from sewage sludge incincerators.

9.4.2 Electrostatic Precipitators

For an electrostatic precipitator (ESP), the monitoring of electrical settings is a means of determining the operating efficiency of the unit. Typically, the voltage, amperage, and spark rate are monitored. The voltage maintains the negative charge on a series of metal plates, which when properly charged attract particulates that have been similarly charged. Variations in the voltage, particularly low voltages, will reduce the quantity of particulates removed.

The amperage is monitored similarly to that for voltage. Thus a drop in the amperage to the collection plates will reduce the quantity of particulate removal from the gas stream. The amperage must be maintained within the manufacturer's specifications to ensure that the collection efficiency is maintained.

The electrical spark rate across the collection plates is also indicative of collection efficiency. Excessive sparking results when too high a voltage is applied to the collection plates. An increase in collection efficiency due to higher plate voltage is offset by the increased disturbance caused by excessive sparking. Sparking rates will vary widely according to the particulate material collected on the plates. The manufacturers' specifications are often the best sources of operating information for ESP units.

9.4.3 Fabric Filter Baghouses

To ensure adequate control of emissions from baghouse fabric filter systems, the pressure drop across the fabric filters must be monitored. The fabric filter's pressure drop must be maintained within a clearly defined range. A pressure drop that becomes too low indicates that some of the gases are not being filtered, and are probably passing through a hole in the bag. A decrease in pressure indicates that maintenance work on the bags is needed immediately.

The pressure drop will increase as the fabric filters become loaded with solids; periodically, therefore, the filter bags must be cleaned to remove the accumulated solids. Without periodic cleaning, the gas flow through the filter bags quickly decreases until the combustion process does not receive enough combustion air to continue properly. Thus the pressure drop across the baghouse is a major parameter requiring limitations under incinerator management practices.

REFERENCES

Adams, R.C., L.E. Keller and E.V. Robb. 1985a. Particulate removal capability of a baghouse filter on the exhaust of a multiple-hearth furnace burning sewage sludge. Draft. Prepared by Radian Corporation for the Water Engineering Research Laboratory (WERL). EPA Contract No. 68-03-3148.

Adams, R.C., G. Bockol, J.A. Maddox and E.V. Robb. 1985b. Particulate removal evaluation of an electrostatic precipitator dust removal system installed on a multiple-hearth incinerator burning sewage sludge. Draft. Prepared by Radian Corporation for the Water Engineering Research Laboratory (WERL), Cincinnati, OH. EPA Contract No. 68-03-3148.

Bennet, R.L., K.T. Knapp and D.L. Duke. 1984. Chemical and physical characterization of municipal sludge incinerator emissions. Report No. EPA 600/3-84-047. NTIS No. PB 84-169325. Research Triangle Park, NC: Environmental Sciences Research Laboratory.

Brunner, C. 1988. Personal Communication from CH2M Hill Co. to E. Crumpler, Washington, DC: EPA Criteria and Standards Division. August 29.

Chico, T. and J. Catalano. 1986. Addendum to the user's guide for MPTER. Report No. EPA 600/8-86-021. Research Triangle Park, NC: Atmospheric Sciences Research Laboratory.

Copeland, B.J. 1977. A study of heavy metal emissions from fluidized-bed incinerators. In: Proceedings of the 30th Industrial Waste Conference May 6-8, 1975, 78-79. Ann Arbor: Ann Arbor Science.

Crowder, J.U. 1988. Revised promulgation package for sewage treatment plants. New Source Performance Standards, July 14.

Dewling, R.T., R.M. Manganelli and G.T. Baer. Fate and behavior of selected heavy metals in incinerated sludge. J. Wat. Pollut. Contr. Fed. 52(10):2552-2557.

Drees, L.M. 1988. Effect of lime and other precipitants or sludge conditioners on conversion of chromium to the hexavalent state when sludge is incinerated. Final report. EPA Contract No. 68-03-3346.

EPA (U.S. Environmental Protection Agency). 1972. Sewage sludge incineration. Report No. EPA R-2-77-040.

EPA (U.S. Environmental Protection Agency). 1979. Process design manual for sludge treatment and disposal. Report No. EPA 625/1-79-011. Washington, DC: Office of Water.

EPA (U.S. Environmental Protection Agency). 1982. User's instruction for the SHORT Z and LONG Z computer programs. Report No. EPA 903/9-82-0004a. Washington, DC: Office of Air and Radiation.

EPA (U.S. Environmental Protection Agency). 1985. Chromium screening study test report, sewage sludge incinerator no. 13, Detroit Water and Sewer Department, Detroit Michigan. EMB Report No. 85-CHM-5. Research Triangle Park, NC: Office of Air Quality and Planning Standards, Emission Measurement Branch.

EPA (U.S. Environmental Protection Agency). 1986a. Sludge incinerator air quality modeling. Washington, DC: Office of Air and Radiation, Model Development and Application Division.

EPA (U.S. Environmental Protection Agency). 1986b. Method development and testing for chromium sewage sludge incinerator no. 13, Detroit Water and Sewer Department, Detroit, Michigan. Research Triangle Park, NC: Office of Air Quality and Planning Standards, Emission Measurement Branch.

EPA (U.S. Environmental Protection Agency). 1986c. Guidelines on air quality models. Revised. Report No. EPA 450/2-78-027R. Research Triangle Park, NC: Environmental Protection Agency.

EPA (U.S. Environmental Protection Agency). 1986d. Industrial source complex (ISC) dispersion model user's guide. 2nd ed. Report No. EPA 450/4-86-005A. Washington, DC: Office of Air and Radiation.

EPA (U.S. Environmental Protection Agency). 1986e. Development of risk assessment methodology for municipal sludge incineration. Revised from ECAO-CIN-486. Cincinnati, OH: Environmental Criteria and Assessment Office.

EPA (U.S. Environmental Protection Agency). 1987a. Chromium emissions from a sewage sludge incinerator. Emissions Test Report. Draft. EPA Contract No. 68-03-3346.

EPA (U.S. Environmental Protection Agency). 1987b. Sewage sludge incineration: ISCLT model sensitivity analysis. EPA Contract No. 68-02-4351.

EPA (U.S. Environmental Protection Agency). 1987c. User guide for sludge incineration model ISCLT - point source (UNAMAP Version 6). Prepared by General Sciences Corporation. EPA Contract No. 68-02-3970, Task 3-16.

EPA (U.S. Environmental Protection Agency). 1988a. Regression results and plots of emission rates for metals and selected organic pollutants. EPA Contract No. 68-03-3453, WA 2-15.

EPA (U.S. Environmental Protection Agency). 1988b. Guidance for writing case-by-case permit requirements for municipal sewage sludge. Draft.

Farrell, J.B. and H. Wall. 1981. Air pollution discharges from ten sewage sludge incinerators. Rev. No. 1, draft. Cincinnati, OH: Municipal Environmental Research Laboratory, Ultimate Disposal Section.

Greenberg, R.R., W.H. Zeller and G.E. Gordon. 1981. Atmospheric emissions of elements of particles from the parkway sewage sludge incinerator. Env. Sci. and Tech. 15(64).

Huber, A.H. 1976. Reprint volume for joint conference on application of air pollution meteorology. Boston, MA: American Meteorological Society.

Huber, A.H. and W.H. Snyder. 1976. Building wake effects on atmospheric diffusion and air quality. Boston, MA: American Meteorological Society.

Incineration, O & M Manual of Practice. 1988. Alexandria, VA: Water Pollution Control Federation.

Klinger, W.A. 1986. Biological sludge incinerator air impacts study. Prepared by TRC Environmental Consultants. Arlington, VA: Arlington County Department of Public Works.

Knisley, D.R., L.M. Lamb and H.M. Smith. 1988. Site 1 draft emission test report, sewage sludge test program. Prepared by Radian Corporation. EPA Contract No. 68-02-6999.

Knisley, D.R., K.W. Barnett and D.J. Holder. 1987. Site 2 draft emission test report, sewage sludge test program. Prepared by Radian Corporation. EPA Contract No. 68-02-6999.

Knisley, D.R., K.W. Barnett and D.J. Holder. 1987. Site 3 draft emission test report, sewage sludge test program. Prepared by Radian Corporation. EPA Contract No. 68-02-6999.

Knisley, D.R., K.W. Barnett and H.A. Palazzolo. 1988. Site 4 draft emission test report, sewage sludge test program. Prepared by Radian Corporation. EPA Contract No. 68-02-6999.

Majima, T., T. Kasakura, M. Naruse and M. Hiraoka. 1977. Studies of pyrolysis process of sewage sludge. In: Prog. Wat. Tech. Vol. 9, 381-396. Great Britain: Pergamon Press.

Umashima, T., M. Naruse and T. Kasakura. 1975. Behavior of Cr^{+6} in incinerator process of sewage sludge. Paper presented at the 12th Annual Meeting of the Association of Japan Sewage Works.

Wall, H. and J. Farrell. 1979. Particulate emissions from municipal wastewater sludge incinerators. Paper presented at the Mid-Atlantic States Section Air Pollution Control Association Meeting, Newark, New Jersey. Cincinnati, OH: Municipal Environmental Research Laboratory.

White, M. and G. Beluzo. 1980. Performance tests and material balance for a fluidized-bed sludge incinerator. Prepared by GCA Corporation. Environmental Protection Agency.

APPENDIX A

Sludge Incinerator Population Database

NAME	CITY, STATE	LATITUDE/ LONGITUDE	URBAN(0)/ RURAL(1)	INCIN. TYPE (MH=1, FB=2, E=3, S-Rf=4)	NUMBER OF INCINERATORS	INDIVIDUAL CAPACITY (dry t/day)	TOTAL CAPACITY (dry t/day)
ANCHORAGE	ANCHORAGE, AK	61 12' 00" 150 02' 00"	0	1	1	1.1	1.1
WRANGELL	WRANGELL, AK	55 44' 00" 133 16' 00"	1	3	1	0.2	0.2
BARSTOW	BARSTOW, CA	34 45' 00" 117 07" 00"	1	2	1	2.5	2.5
LAKE ARROWHEAD	LAKE ARROWHEAD, CA	34 16' 08" 117 11' 08"	1	1	1	4.8	4.8
PALO ALTO	PALO ALTO, CA	37 27' 40" 122 06' 50"	0	1	2	5.4	6
SACREMENTO	SACREMENTO, CA	38 31' 12" 121 31' 22"	0	1	1	7.2	7.2
SAN MATEO	SAN MATEO, CA	37 32' 00" 122 27' 00"	0	1	1	4.9	4.9
S. LAKE TAHOE	LAKE TAHOE, CA	39 01' 00" 119 52' 00"	1	1	1	0.8	0.8
C. CONTRA COSTA	WALNUT CREEK, CA	38 02' 44" 122 05' 55"	1	1	2 (1/time)	44	44
YOSEMITE	YOSEMITE NT. PK., CA	37 52' 00" 119 52' 00"	1	1	1	3.4	3.4
MATTABASSETT	CROMWELL, CT	41 35' 03" 72 39" 04"	1	1	1	12.5	12.5
HARTFORD	HARTFORD, CT	41 43' 55" 72 39" 10"	0	1	3 (2/time)	168	336
EAST SHORE	NEW HAVEN, CT	41 16' 50" 72 54' 30"	0	1	1	29.2	29.2
NEW CANAAN	NEW CANAAN, CT	41 08' 20" 73 29' 00"	1	4	1	38.9 (108 t/d ref.)	38.9
NEW LONDON	NEW LONDON, CT	41 21' 17" 72 05' 06"	0	1	2	25.9	51.8
NORWALK	NORWALK, CT	41 06' 06" 73 24' 55"	1	2	1	36	36
STAMFORD	STAMFORD, CT	41 04' 00" 73 31' 00"	0	4	1	94.7 (60 t/d ref.)	94.7
WATERBURY	WATERBURY, CT	41 31' 19" 73 02' 51"	0	1	1	6.5	6.5

NAME	TREATMENT VOLUME (mgal/day)	OPERATING TIME (days/week)	BUILDING AREA (sq meters)	EMISSION TYPE (stack=H)	VENT TYPE (VERT.=0 NON-VERT.=1)	BASE. CONTROLS (0=0, I=1, V=2, V/I=3, WCy=4, WS=5, SC=6, ESP=7, WCy/I=8, Pk.T=9, V/Pk.T=10)
ANCHORAGE	24	6	300	H	0	1
WRANGELL	0.39	0.5	300	H	0	2
BARSTOW	2	6	300	H	0	6
LAKE ARROWHEAD	0.8	3.5	300	H	0	5
PALO ALTO	26	6	600	H	0	1
SACREMENTO	136	7	300	H	0	2
SAN MATEO	1.5	6	300	H	0	3
S. LAKE TAHOE	6	6	300	H	0	1
C. CONTRA COSTA	35	7	600	H	0	1
YOSEMITE	2	0.6	300	H	0	3
MATTABASSETT	20	6	300	H	0	4
HARTFORD	48	6	900	H	0	5
EAST SHORE	9	5	300	H	0	2
NEW CANAAN	1.4	2.1	1500	H	0	2
NEW LONDON	3	1.6	600	H	0	3
NORWALK	15 (9-typ.)	1.7	300	H	0	2
STAMFORD	19.4	6	1500	H	0	7
WATERBURY	22	6	300	H	0	1

NAME	BASELINE STACK HEIGHT (meters)	BASELINE STACK DIAM. (meters)	BASE. TOTAL GAS FLOW (acmm)	BASE. GAS VELOC./STACK (meters/sec)	BASELINE STACK GAS TEMP (K)
ANCHORAGE	19.1	0.5	168.6	14.3	332
WRANGELL	12.1	1	0.82	0.1	322
BARSTOW	4.5	0.2	28.3	15.0	322
LAKE ARROWHEAD	9.1	0.9	25.44	0.7	322
PALO ALTO	13.6	0.8	31.8	1.1	322
SACREMENTO	18.3	0.9	38.16	1.0	322
SAN MATEO	19.1	0.9	25.97	0.7	322
S. LAKE TAHOE	18.2	0.9	4.24	0.1	422
C. CONTRA COSTA	21.3	1.2	233.2	3.4	322
YOSEMITE	10.7	0.6	18.02	1.1	322
MATTABASSETT	19.1	0.9	66.25	1.7	322
HARTFORD	19.1	1.5	1780.8	16.8	322
EAST SHORE	19.1	0.9	154.76	4.1	322
NEW CANAAN	24.4	1.5	1069	9.8	350
NEW LONDON	19.1	0.9	352	9.2	317
NORWALK	10.7	0.9	680	17.8	322
STAMFORD	19.1	0.9	528	13.8	348
WATERBURY	6.1	0.3	34.45	8.1	322

NAME	CITY, STATE	LATITUDE/ LONGITUDE	URBAN(0)/ RURAL(1)	INCIN. TYPE (MH=1, FB=2, E=3, S-Rf=4)	NUMBER OF INCINERATORS	INDIVIDUAL CAPACITY (dry t/day)	TOTAL CAPACITY (dry t/day)
JACKSONVILLE	JACKSONVILLE, FL	30 21' 08" 81 37' 38"	0	1	1	28.4	28.4
ATLANTA BOLTON RD.	ATLANTA, GA	33 49' 27" 84 27' 33"	0	1	2	64.8	129.6
ATLANTA UTOY CREEK	ATLANTA, GA	33 44' 45" 84 33' 58"	0	1	1	8.1	8.1
COBB COUNTY	MARIETTA, GA	33 57' 00" 84 29' 00"	0	1	1	13.8	13.8
DEACTUR	DECATUR, GA	33 40' 08" 84 13' 41"	0	3	2	22.4	44.8
GAINESVILLE	GAINESVILLE, GA	34 16' 00" 83 52' 25"	1	3	2 (1/time)	5.5	5.5
SAVANNAH	SAVANNAH, GA	32 04' 28" 81 03' 48"	0	1	2 (1/time)	12	12
SAND ISLAND	HONOLULU, HA	21 22' 45" 157 59' 11"	0	1	2 (1/time)	25.9	25.9
INDIANAPOLIS	INDIANAPOLIS, IN	39 43' 37" 86 11' 41"	0	1	8	45.4	362.9
CEDAR RAPIDS	CEDAR RAPIDS, IA	41 33' 00" 91 39' 00"	0	1	1	24.3	24.3
DAVENPORT	DAVENPORT, IA	41 35' 00" 90 33' 00"	0	1	1	35.6	35.6
DUBUQUE	DUBUQUE, IA	42 28' 17" 90 38' 56"	1	2	2 (1/time)	7.5	7.5
KANSAS CITY	KANSAS CITY, KA	39 08' 00" 94 36' 00"	0	2	2	3.2	6.4
TURKEY CREEK	SHAWNEE MISSION, KA	39 00' 00" 94 41' 00"	0	1	1	17.8	17.8
LAKE CHARLES	LAKE CHARLES, LA	30 11' 40" 93 12' 20"	0	1	1	6	6
NEW ORLEANS	NEW ORLEANS, LA	29 56' 59" 90 00' 43"	0 0	1 2	1 1	16.2 41	16.2 41
OCEAN CITY	OCEAN CITY, MD	38 20' 30" 75 04' 10"	1	2	1	7.2	7.2
PATAPSCO	BALTIMORE, MD	39 14' 07"	0	1	3	49.2	98.4

NAME	TREATMENT VOLUME (mgal/day)	OPERATING TIME (days/week)	BUILDING AREA (sq meters)	EMISSION TYPE (stack=H)	VENT TYPE (VERT.=0 NON-VERT.=1)	BASE. CONTROLS (0=0, I=1, V=2, V/I=3, WCy=4, WS=5, SC=6, ESP=7, WCy/I=8, Pk. T=9, V/Pk. T=10)
JACKSONVILLE	30	6	300	H	0	3
ATLANTA BOLTON RD.	84	6	600	H	0	3
ATLANTA UTOY CREEK		6	300	H	0	2
COBB COUNTY	17	7	300	H	0	3
DEACTUR	36	6	600	H	0	3
GAINESVILLE	14	7	600	H	0	2
SAVANNAH	18	7	600	H	0	3
SAND ISLAND	62	7	600	H	0	3
INDIANAPOLIS		7	2400	H	0	4
CEDAR RAPIDS	25	6	300	H	0	3
DAVENPORT	19	6	300	H	0	3
DUBUQUE	9	5	600	H	0	10
KANSAS CITY	7 25	5	600	H	0	2
TURKEY CREEK	6	5	300	H	0	5
LAKE CHARLES	5	5	300	H	0	1
NEW ORLEANS		6	300	H	0	4
	71	6	300	H	0	2
OCEAN CITY	7	5.8	300	H	0	1
PATAPSCO		7	900	H	0	3

NAME	BASELINE STACK HEIGHT (meters)	BASELINE STACK DIAM. (meters)	BASE. TOTAL GAS FLOW (acmm)	BASE. GAS VELOC./STACK (meters/sec)	BASELINE STACK GAS TEMP (K)
JACKSONVILLE	21.2	0.9	150.52	3.9	322
ATLANTA BOLTON RD.	30.3	0.8	269	8.9	322
ATLANTA UTOY CREEK	24.2	0.6	42.93	2.5	322
COBB COUNTY	18.3	0.6	104.94	6.2	322
DEACTUR	22.7	0.5	183.68	15.6	322
GAINESVILLE	7.6	0.5	89.1	7.6	322
SAVANNAH	18.3	0.5	63.6	5.4	322
SAND ISLAND	30.5	4.3	137.27	0.2	322
INDIANAPOLIS	4 @ 12.2 1 @ 22.9	0.9 1.8	1923.37	6.3 6.3	322
CEDAR RAPIDS	12.1	1.2	128.79	1.9	322
DAVENPORT	9.4	1.5	1375	13.0	322
DUBUQUE	21.2	0.4	194	25.7	322
KANSAS CITY	22.7	0.5	111	9.4	322
TURKEY CREEK	12.1	3.6	94.34	0.2	322
LAKE CHARLES	12.2	0.6	31.8	1.9	322
NEW ORLEANS	21.3 24.4	1.5 0.5	85.86 168.1	0.8 14.3	322
OCEAN CITY	10.7	0.2	29.52	15.6	311
PATAPSCO	3 @ 35.1	1.2	521.52	2.6	322

NAME	CITY, STATE	LATITUDE/ LONGITUDE 76 33' 23"	URBAN(0)/ RURAL(1)	INCIN. TYPE (MH=1, FB=2, E=3, S-Rf=4)	NUMBER OF INCINERATORS (2/time)	INDIVIDUAL CAPACITY (dry t/day)	TOTAL CAPACITY (dry t/day)
CHICOPEE	CHICOPEE, MA	42 09' 13" 72 37' 22"	0 0	1	1 1	9.6 7.2	9.6 7.2
FITCHBURG	FITCHBURG, MA	42 32' 48" 71 45' 08"	0	1	1	38.9	38.9
LAWRENCE	N. ANDOVER, MA	42 42' 58" 71 08' 05"	0	1	2	45.4	90.8
NEW BEDFORD	NEW BEDFORD, MA	41 35' 38" 70 55' 10"	0	1	1	16.2	16.2
UPPER BLACKSTONE	MILLBURY, MA	42 12' 55" 71 47' 24"	1	1	3	11.7	35.1
ANN ARBOR	ANN ARBOR, MI	42 17' 58" 83 44' 42"	0	1	1	54	54
BAY CITY	BAY CITY, MI	43 35' 00" 83 56' 00"	1	1	1	3.2	3.2
DETROIT COMPLEX 1	DETROIT, MI	42 16' 35" 83 06' 26"	0	1	6	68	408
DETROIT COMPLEX 2	DETROIT, MI	42 16' 35" 83 06' 26"	0	1	8	84.2	673.6
EAST LANSING	EAST LANSING, MI	42 44' 00" 84 31' 00"	0	1	2	16.2	32.4
GRAND RAPIDS	GRAND RAPIDS, MI	42 53' 00" 85 38' 00"	0 0	1	1 1	22.7 9.7	32.4
KALAMAZOO	KALAMAZOO, MI	42 12' 00" 85 36' 00"	0	1	1	48	48
PONTIAC	PONTIAC, MI	42 38' 15" 83 15' 16"	0	1	1	64.8	64.8
PORT HURON	PORT HURON, MI	42 57' 50" 82 29' 15"	1	2	1	7.6	7.6
WAYNE CO.	WYANDOTTE, MI	42 11' 12" 83 09' 41"	0	1	4	60.8	243.2
WARREN	WARREN, MI	42 32' 00" 83 01' 00"	0	1	1	25.9	25.9
YPSILANTI	YPSILANTI, MI	42 13' 47" 83 32' 45"	0	1	1	54	54

NAME	TREATMENT VOLUME (mgal/day)	OPERATING TIME (days/week)	BUILDING AREA (sq meters)	EMISSION TYPE (stack=H)	VENT TYPE (VERT.=0 NON-VERT.=1)	BASE. CONTROLS (0=0, I=1, V=2, V/I=3, WCy=4, WS=5, SC=6, ESP=7, WCy/I=8, Pk.T=9, V/Pk.T=10)
CHICOPEE	5	6 6	600	H	0	3 3
FITCHBURG	1	2	300	H	0	1
LAWRENCE	38	5	600	H	0	9
NEW BEDFORD		6	300	H	0	1
UPPER BLACKSTONE	32	6	900	H	0	1
ANN ARBOR	16	5	300	H	0	5
BAY CITY	32	7	300	H	0	5
DETROIT COMPLEX 1	299	7	1800	H	0	3
DETROIT COMPLEX 2	399	7	2400	H	0	1
EAST LANSING	11	7	600	H	0	5
GRAND RAPIDS	50	4.4 4.4	600	H	0	2 2
KALAMAZOO	33	7	300	H	0	3
PONTIAC	20	6	300	H	0	5
PORT HURON	14	1.7	300	H	0	1
WAYNE CO.	45	7	1200	H	0	5
WARREN		6	300	H	0	8
YPSILANTI	10	5	300	H	0	2

NAME	BASELINE STACK HEIGHT (meters)	BASELINE STACK DIAM. (meters)	BASE. TOTAL GAS FLOW (acmm)	BASE. GAS VELOC./STACK (meters/sec)	BASELINE STACK GAS TEMP (K)
CHICOPEE	15.1 15.1	0.5 0.5	50.88 29.52	4.3 2.5	311
FITCHBURG	15.1	0.6	206.17	12.1	311
LAWRENCE	48.4 48.4	0.9 0.9	481.24	6.3 6.3	311 311
NEW BEDFORD	12.1	0.9	85.86	2.2	339
UPPER BLACKSTONE	27.2	0.9	186.03	4.9	316
ANN ARBOR	36.3	0.9	713	18.7	322
BAY CITY	19.1	0.9	16.96	0.4	322
DETROIT COMPLEX 1	6 @ 19.1	2.1	2162.4	1.7	322
DETROIT COMPLEX 2	8 @ 19.1	2.1	3570.08	2.2	322
EAST LANSING	13.7 12.2	0.9 1.2	171.72	1.6 0.7	322
GRAND RAPIDS	19.1	0.9	171.72	4.5	322
KALAMAZOO	18.3	0.5	254.4	21.6	322
PONTIAC	18.3	0.5	343.44	29.1	322
PORT HURON	11.6	0.5	31.16	2.6	322
WAYNE CO.	19.1	1.5	1288.96	12.1	322
WARREN	19.1	0.9	137.27	3.6	322
YPSILANTI	18.3	1	651.3	13.8	322

NAME	CITY, STATE	LATITUDE/ LONGITUDE	URBAN(0)/ RURAL(1)	INCIN. TYPE (MH=1, FB=2, E=3, S-Rf=4)	NUMBER OF INCINERATORS	INDIVIDUAL CAPACITY (dry t/day)	TOTAL CAPACITY (dry t/day)
DULUTH	DULUTH, MN	46 48' 00" 92 03' 00"	0	4	2 (1/time)	34 (120 t/d ref.)	34
METROPOLITAN	ST. PAUL, MN	44 55' 35" 93 02' 44"	0	1	6	129.6	777.6
SENECA	ST. PAUL, MN	44 49' 51" 93 12' 26"	0	1	2	9.7	19.4
INDEPENDENCE	INDEPENDENCE, MO	39 04' 00" 94 27' 00"	0	2	1	9.7	9.7
ST. LOUIS BISSEL POINT	ST. LOUIS, MO	38 40' 40" 90 11' 20"	0	1	5	64.8	324
ST. LOUIS LEMAY	ST. LOUIS, MO	38 31' 22" 90 16' 02"	0	1	4 (3/time)	48.6	145.8
KANSAS CITY	KANSAS CITY, MO	39 06' 50" 94 31' 00"	0	1	1	45.4	45.4
ROUND HILL	LAKE TAHOE, NV	39 11' 00" 119 53' 00"	1	2	1	4.5	4.5
LEBANON	LEBANON, NH	43 44' 00" 72 15" 00"	1	1	1	7.2	7.2
ATLANTIC CITY	ATLANTIC CITY, NJ	39 23' 00" 74 26' 00"	0	1	1	25.9	25.9
PARSIPPANY	PARSIPPANY, NJ	40 53' 50" 74 23' 30"	0	1	2	38.9	77.8
SUMMERSET-RARITAN	RARITAN, NJ	40 34' 00" 74 37' 00"	0	1	1	12	12
STONY BROOK	PRINCETON, NJ	40 22' 47" 74 37' 22"	1	1	2 (1/time)	39.5	39.5
UNION BEACH	UNION BEACH, NJ	40 26' 22" 74 07' 43"	1	2	1	30	30
WALDWICK	WALDWICK, NJ	41 00' 23" 74 07' 12"	0	1	1	18	18
WAYNE	WAYNE, NJ	40 55' 00" 74 14' 00"	0	1	2	48	96
ALBANY NORTH	ALBANY, NY	42 40' 28" 73 43' 30"	0	1	2	240	129.6
ALBANY SOUTH	ALBANY, NY	42 37' 00" 73 45' 00"	0	1	2	45.9	91.8

NAME	TREATMENT VOLUME (mgal/day)	OPERATING TIME (days/week)	BUILDING AREA (sq meters)	EMISSION TYPE (stack=H)	VENT TYPE (VERT.=0 NON-VERT.=1)	BASE. CONTROLS (0=0, I=1, V=2, V/I=3, WCy=4, WS=5, SC=6, ESP=7, WCy/I=8, Pk. T=9, V/Pk. T=10)
DULUTH		7	1500	H	0	2
METROPOLITAN	250	6	1800	H	0	3
SENECA	24	6	600	H	0	3
INDEPENDENCE	8	6	300	H	0	3
ST. LOUIS BISSEL POINT	140	7	1500	H	0	4
ST. LOUIS LEMAY	110	7	1200	H	0	3
KANSAS CITY		7	300	H	0	5
ROUND HILL	1	6	300	H	0	5
LEBANON	1	1.2	300	H	0	3
ATLANTIC CITY	57	7	300	H	0	3
PARSIPPANY	25	7	600	H	0	0
SUMMERSET-RARITAN		7	300	H	0	3
STONY BROOK	4	7	600	H	0	3
UNION BEACH	33	7	300	H	0	4
WALDWICK	8	5	300	H	0	3
WAYNE	24	5	600	H	0	5
ALBANY NORTH		6	600	H	0	1
ALBANY SOUTH		6	600	H	0	1

NAME	BASELINE STACK HEIGHT (meters)	BASELINE STACK DIAM. (meters)	BASE. TOTAL GAS FLOW (acmm)	BASE. GAS VELOC./STACK (meters/sec)	BASELINE STACK GAS TEMP (K)
DULUTH	30.5	1.1	279	4.9	350
METROPOLITAN	45.7	1.5	4121.28	38.8	322
SENECA	30.5	0.9	102.82	2.7	322
INDEPENDENCE	15.2	1.2	152.9	2.3	322
ST. LOUIS BISSEL POINT	45.7	4.6	1717.2	1.7	322
ST. LOUIS LEMAY	61	3.7	772.74	1.2	322
KANSAS CITY	61.0	3	2350	5.5	322
ROUND HILL	15.2	0.4	18.45	2.4	322
LEBANON	18.3	0.3	38.16	9.0	322
ATLANTIC CITY	18.3	0.8	137.27	4.5	322
PARSIPPANY	7.6	0.9	412.34	10.8	322
SUMMERSET-RARITAN	12.1	0.5	63.6	5.4	322
STONY BROOK	30.5	0.8	209.35	6.9	322
UNION BEACH	12.2	0.6	123	7.2	322
WALDWICK	12.1	0.4	95.4	12.6	322
WAYNE	10.7	0.6	508.8	30.0	322
ALBANY NORTH	7.6	1.2	686.88	10.1	322
ALBANY SOUTH	7.6	1.2	486.54	7.2	322

NAME	CITY, STATE	LATITUDE/ LONGITUDE	URBAN(0)/ RURAL(1)	INCIN. TYPE (MH=1, FB=2, E=3, S-Rf=4)	NUMBER OF INCINERATORS	INDIVIDUAL CAPACITY (dry t/day)	TOTAL CAPACITY (dry t/day)
ARLINGTON	ARLINGTON, NY	41 38' 56" 73 56' 42"	0	2	1	8.4	8.4
AUBURN	AUBURN, NY	42 56' 39" 76 35' 48"	0	1	1	40.5	40.5
BEACON	BEACON, NY	41 30' 00" 73 58' 00"	1	1	1	9.7	9.7
BIRDS ISLAND	BUFFALO, NY	42 57' 07" 78 54' 36"	0	1	3 (2/time)	91.8	183.6
GLEN COVE	NEW YORK, NY	40 51' 53" 73 38' 28"	0	4	1	25 (225 t/d ref.)	25
HAMBURG	ERIE CO., NY	42 42' 00" 78 52' 00"	1	2	2	144	288
LITTLE FALLS	LITTLE FALLS, NY	43 02' 43" 74 51' 33"	1	2	1	3.9	3.9
ORANGETOWN	ORANGETOWN, NY	41 02' 30" 73 53' 30"	0	1	1	16.8	16.8

NAME	TREATMENT VOLUME (mgal/day)	OPERATING TIME (days/week)	BUILDING AREA (sq meters)	EMISSION TYPE (stack=H)	VENT TYPE (VERT.=0 NON-VERT.=1)	BASE. CONTROLS (0=0, I=1, V=2, V/I=3, WCy=4, WS=5, SC=6, ESP=7, WCy/I=8, Pk.T=9, V/Pk.T=10)
ARLINGTON		3	300	H	0	5
AUBURN	9	3.5	300	H	0	5
BEACON	4	4	300	H	0	5
BIRDS ISLAND	178	7	900	H	0	2
GLEN COVE	5.7	7	1500	H	0	7
HAMBURG	16	7	600	H	0	3
LITTLE FALLS		0.3	300	H	0	2
ORANGETOWN	7	4.2	300	H	0	3

NAME	BASELINE STACK HEIGHT (meters)	BASELINE STACK DIAM. (meters)	BASE. TOTAL GAS FLOW (acmm)	BASE. GAS VELOC./STACK (meters/sec)	BASELINE STACK GAS TEMP (K)
ARLINGTON	11.5	0.61	34.44	2.0	322
AUBURN	20.4	0.9	214.65	5.6	322
BEACON	12.2	1.2	51.41	0.8	322
BIRDS ISLAND	29.3	1.8	1784	11.7	322
GLEN COVE	61	3.7	813	1.3	408
HAMBURG	15.2	1.5	1180.8	11.1	322
LITTLE FALLS	19.8	0.6	15.99	0.9	322
ORANGETOWN	18.3	1.2	89.04	1.3	322

NAME	CITY, STATE	LATITUDE/ LONGITUDE	URBAN(0)/ RURAL(1)	INCIN. TYPE (MH=1, FB=2, E=3, S-Rf=4)	NUMBER OF INCINERATORS	INDIVIDUAL CAPACITY (dry t/day)	TOTAL CAPACITY (dry t/day)
ROCHESTER GATES-CHILL	ROCHESTER, NY	43 05' 00" 77 43' 00"	0	1	2	18	36
ROCHESTER N.W. QUAD	ROCHESTER, NY	43 11' 00" 77 38' 00"	0	1	2	24	48
ROCHESTER VAN LARE	ROCHESTER, NY	43 08' 00" 77 32' 00"	0	1	2	36	72
SCHENECTADY	SCHENECTADY, NY	42 50' 24" 73 55' 17"	0	1	1	140	140
UTICA	ONEIDA CO., NY	43 03' 00" 75 12' 00"	1	1	2	20	40
WATERTOWN	WATERTOWN, NY	43 58' 00" 75 54' 00"	1	1	1	21	21
GREENSBORO	GREENSBORO, NC	35 59' 00" 79 45' 00"	0	1	1	45.4	45.4
ROCKY MOUNT	ROCKY MOUNT, NC	35 57' 13" 77 47' 07"	1	1	1	7.5	7.5
SHELBY	SHELBY, NC	35 14' 00" 81 34' 00"	1	2	1	16.2	16.2
AKRON	AKRON, OH	41 09' 20" 81 33' 57"	1	1	2	9.7	19.4
CANTON	CANTON, OH	40 45' 20" 81 22' 18"	0	1	2 (1/time)	25	25
CINCINNATI MILL CREEK	CINCINNATI, OH	39 06' 47" 84 32' 52"	0	1	4	42.1	168.4
CLEVELAND SOUTH	CLEVELAND, OH	41 24' 00" 81 49' 00"	0	1	4	64.8	259.2
CLEVELAND WEST	CLEVELAND, OH	41 25' 00" 81 40' 00"	0	1	2	97.2	194.4
COLUMBUS JACKSON PIKE	COLUMBUS, OH	39 54' 23" 83 00' 31"	0	1	1	38.9	38.9
COLUMBUS SOUTH	COLUMBUS, OH	39 48' 52" 83 00' 50"	0	1	2	22.7	45.4
EUCLID	EUCLID, OH	41 36' 50" 81 31' 48"	0	1	2	10.8	21.6
YOUNGSTOWN	YOUNGSTOWN, OH	41 05' 40"	0	1	1	40.5	40.5

NAME	TREATMENT VOLUME (mgal/day)	OPERATING TIME (days/week)	BUILDING AREA (sq meters)	EMISSION TYPE (stack=H)	VENT TYPE (VERT.=0 NON-VERT.=1)	BASE. CONTROLS (0=0, I=1, V=2, V/I=3, WCy=4, WS=5, SC=6, ESP=7, WCy/I=8, Pk.T=9, V/Pk.T=10)
ROCHESTER GATES-CHILL	11	5	600	H	0	5
ROCHESTER N.W. QUAD		5	600	H	0	5
ROCHESTER VAN LARE	69	7	600	H	0	5
SCHENECTADY	14	5	300	H	0	5
UTICA		5	600	H	0	2
WATERTOWN	3	0.3	300	H	0	5
GREENSBORO	10	7	300	H	0	1
ROCKY MOUNT	10	3.5	300	H	0	3
SHELBY	4	5	300	H	0	1
AKRON	79	6	600	H	0	2
CANTON	33	7	600	H	0	1
CINCINNATI MILL CREEK	107	7	1200	H	0	1
CLEVELAND SOUTH	110	7	1200	H	0	5
CLEVELAND WEST	50	7	600	H	0	5
COLUMBUS JACKSON PIKE	32	7	300	H	0	2
COLUMBUS SOUTH		7	600	H	0	2
EUCLID	17	7	600	H	0	5
YOUNGSTOWN	29	7	300	H	0	6

NAME	BASELINE STACK HEIGHT (meters)	BASELINE STACK DIAM. (meters)	BASE. TOTAL GAS FLOW (acmm)	BASE. GAS VELOC./STACK (meters/sec)	BASELINE STACK GAS TEMP (K)
ROCHESTER GATES-CHILL	8.5	0.7	190.8	8.3	322
ROCHESTER N.W. QUAD	10.4	0.6	254.4	15.0	322
ROCHESTER VAN LARE	61	6.1	381.6	0.2	322
SCHENECTADY	5.4	1.2	742	10.9	322
UTICA	9.1	0.9	212	5.5	322
WATERTOWN	12.2	1.5	111.3	1.0	322
GREENSBORO	27.4	0.9	240.62	6.3	322
ROCKY MOUNT	19.1	0.5	39.75	3.4	322
SHELBY	12.2	0.5	66.42	5.6	311
AKRON	19.1	0.9	102.82	2.7	322
CANTON	12.2	0.9	132.5	3.5	322
CINCINNATI MILL CREEK	4 @ 19.1	0.6	548	8.1	318
CLEVELAND SOUTH	18.0	1.5	736.2	6.9	322
CLEVELAND WEST	19.8	0.9	453.1	11.9	311
COLUMBUS JACKSON PIKE	19.1	1.5	792.9	7.5	322
COLUMBUS SOUTH	19.1	1.5	869.3	8.2	322
EUCLID	19.1	0.9	114.48	3.0	322
YOUNGSTOWN	19.1	0.9	214.65	5.6	322

NAME	CITY, STATE	LATITUDE/ LONGITUDE 80 38' 27"	URBAN(0)/ RURAL(1)	INCIN. TYPE (MH=1, FB=2, E=3, S-Rf=4)	NUMBER OF INCINERATORS	INDIVIDUAL CAPACITY (dry t/day)	TOTAL CAPACITY (dry t/day)
TIGARD	TIGARD, OR	45 23' 37" 122 45' 33"	1	1	2 (1/time)	15	15
DELORA-CHESTER	CHESTER, PA	39 49' 29" 75 23' 41"	0	1	2	9.7	19.4
DURYEA	DURYEA, PA	41 18' 55" 75 44' 40"	0	1	1	25.9	25.9
ERIE	ERIE, PA	42 08' 28" 80 04' 36"	0	1	2	67.5	135
HARRISBURG	HARRISBURG, PA	40 16' 00" 76 55' 00"	0	4	2	67.7 (394 t/d ref.)	135.4
HATFIELD	COLMAR, PA	40 15' 45" 75 11' 25"	1	1	1	5.7	5.7
HAZLETON	HAZLETON, PA	40 57' 44" 76 01' 31"	0	2	1	4.5	4.5
HERSHEY	HERSHEY, PA	40 18' 20" 76 42' 05"	1	1	1	40.5	40.5
JOHNSTOWN	JOHNSTOWN, PA	40 19' 00" 78 56' 00"	0	1	1	8.1	8.1
KISKI VALLEY	APPOLO, PA	40 36' 34" 79 34' 03"	0	1	7	19.4	136.1
TYRONE	TYRONE, PA	39 45' 50" 78 15' 28"	1	2	1	5.1	5.1
UPPER GWYNEDD	N. WALES, PA	40 12' 00' 75 16' 30"	1	2	1	1.1	1.1
WYOMING VALLEY	WILKES-BARRE, PA	41 13' 59" 75 56' 11"	0	1	1	32.4	32.4
YORK	YORK, PA	39 59' 11" 76 43' 27"	0	1	2	19.4	38.8
CRANSTON	CRANSTON, RI	41 45' 00" 71 26' 00"	0	1	2 (1/time)	20.4	20.4
CHARLESTON	CHARLESTON, SC	32 45' 10" 79 57' 00"	0	1	1	32.4	32.4
COLUMBIA	COLUMBIA, SC	33 59' 00" 81 00' 00"	0	1	2	4.1	8.2

NAME	TREATMENT VOLUME (mgal/day)	OPERATING TIME (days/week)	BUILDING AREA (sq meters)	EMISSION TYPE (stack=H)	VENT TYPE (VERT.=0 NON-VERT.=1)	BASE. CONTROLS (0=0, I=1, V=2, V/I=3, WCy=4, WS=5, SC=6, ESP=7, WCy/I=8, Pk.T=9, V/Pk.T=10)
TIGARD	8	5.8	600	H	0	3
DELORA-CHESTER	36	7	600	H	0	5
DURYEA	6	7	300	H	0	5
ERIE	63	7	600	H	0	5
HARRISBURG		7	1500	H	0	7
HATFIELD	2	7	300	H	0	5
HAZLETON	6	1	300	H	0	5
HERSHEY	2	1	300	H	0	1
JOHNSTOWN		5	300	H	0	0
KISKI VALLEY	3	3.5	2100	H	0	5
TYRONE	6	3.3	300	H	0	2
UPPER GWYNEDD	2	1.4	300	H	0	5
WYOMING VALLEY	25	3	300	H	0	5
YORK	26	7	600	H	0	5
CRANSTON	9	2.9	600	H	0	3
CHARLESTON	15	4	300	H	0	5
COLUMBIA	22	7	600	H	0	5

NAME	BASELINE STACK HEIGHT (meters)	BASELINE STACK DIAM. (meters)	BASE. TOTAL GAS FLOW (acmm)	BASE. GAS VELOC./STACK (meters/sec)	BASELINE STACK GAS TEMP (K)
TIGARD	15.2	0.8	79.5	2.6	322
DELORA-CHESTER	19.1	0.9	102.82	2.7	322
DURYEA	13.7	0.9	137.27	3.6	322
ERIE	30.5	1.5	1132.7	10.7	322
HARRISBURG	45.7	2.3	6446	25.6	544
HATFIELD	6.1	0.2	30.21	16.0	322
HAZLETON	9.1	0.8	18.45	0.6	322
HERSHEY	18.3	0.9	368.1	9.6	322
JOHNSTOWN	12.1	1.2	42.93	0.6	322
KISKI VALLEY	19.1	1.5	721.33	6.8	322
TYRONE	12.8	0.3	20.91	4.9	322
UPPER GWYNEDD	16.8	0.5	4.51	0.4	322
WYOMING VALLEY	13.1	0.9	171.72	4.5	322
YORK	9.1 20.7	0.6 1.2	205.64	5.2 1.7	322
CRANSTON	19.1	0.9	108.12	2.8	322
CHARLESTON	6.1	0.6	171.72	10.1	322
COLUMBIA	22.9	0.8	43.46	1.4	322

NAME	CITY, STATE	LATITUDE/ LONGITUDE	URBAN(0)/ RURAL(1)	INCIN. TYPE (MH=1, FB=2, E=3, S-Rf=4)	NUMBER OF INCINERATORS	INDIVIDUAL CAPACITY (dry t/day)	TOTAL CAPACITY (dry t/day)
BRISTOL	BRISTOL, TN	36 30' 02" 82 17' 34"	1	1	1	16.2	16.2
MARYVILLE	MARYVILLE, TN	35 47' 00" 84 02' 00"	1	1	1	13	13
NEWPORT	NEWPORT, TN	35 56' 29" 83 11' 02"	1	1	1	7.8	7.8
ARLINGTON	ARLINGTON, VA	38 50' 38" 77 03' 15"	0	1	2 (1/time)	34.8	34.8
FAIRFAX	FAIRFAX, VA	38 41' 59" 77 12' 23"	0 0	1 1	2 2	45.4 32.4	90.8 64.8
HOPEWELL	HOPEWELL, VA	37 14' 00" 77 19' 00"	0	1	1	8.1	8.1
NEWPORT NEWS BOAT HARBOR	NEWPORT NEWS, VA	36 57' 30" 76 24' 55"	0	1	2	4.9	9.8
WILLIAMSBURG	WILLIAMSBURG, VA	37 14' 00" 76 42' 00"	1	1	2 (1/time)	5.3	5.3
EDMONDS	EDMONDS, WA	47 48' 45" 122 23' 23"	1	2	1	1.6	1.6
LYNNWOOD	LYNNWOOD, WA	47 50' 53" 122 20' 29"	1	2	1	0.7	0.7
VANCOUVER	VANCOUVER, WA	45 38' 07" 122 42' 03"	0	1	1	34	34
BROOKFIELD	BROOKFIELD, WI	43 01' 50" 88 12' 55"	0	1	1	3.9	3.9
GREEN BAY	GREEN BAY, WI	44 31' 00" 88 02' 00"	0	1	2 (1/time)	87.5	87.5
MILWAUKEE	MILWAUKEE, WI	43 01' 00" 87 58' 00"	0	1	1	7.1	7.1

NAME	TREATMENT VOLUME (mgal/day)	OPERATING TIME (days/week)	BUILDING AREA (sq meters)	EMISSION TYPE (stack=H)	VENT TYPE (VERT. =0 NON-VERT. =1)	BASE. CONTROLS (0=0, I=1, V=2, V/I=3, WCy=4, WS=5, SC=6, ESP=7, WCy/I=8, Pk. T=9, V/Pk. T=10)
BRISTOL	10	7	300	H	0	5
MARYVILLE	3	7	300	H	0	3
NEWPORT		0.8	300	H	0	5
ARLINGTON	23	6	600	H	0	3
FAIRFAX	23	7 7	600 600	H	0	1 4
HOPEWELL	40	7	300	H	0	5
NEWPORT NEWS BOAT HARBOR	18	7	600	H	0	5
WILLIAMSBURG	6	7	600	H	0	5
EDMONDS	4	5.8	300	H	0	5
LYNNWOOD		4.7	300	H	0	5
VANCOUVER	18	3	300	H	0	5
BROOKFIELD	10	0.9	300	H	0	1
GREEN BAY	29	4.7	600	H	0	5
MILWAUKEE	72	3	300	H	0	5

NAME	BASELINE STACK HEIGHT (meters)	BASELINE STACK DIAM. (meters)	BASE. TOTAL GAS FLOW (acmm)	BASE. GAS VELOC./STACK (meters/sec)	BASELINE STACK GAS TEMP (K)
BRISTOL	19.1	0.9	85.86	2.2	322
MARYVILLE	18.3	0.6	523.9	30.9	322
NEWPORT	11.0	0.9	41.34	1.1	322
ARLINGTON	19.1	0.9	184.44	4.8	322
FAIRFAX	12.2	1.5	824.68	7.8	322
HOPEWELL	15.2	0.5	42.93	3.6	322
NEWPORT NEWS BOAT HARBOR	15.2	1.5	13.6	0.1	322
WILLIAMSBURG	18.3	0.9	28.09	0.7	366
EDMONDS	9.1	0.9	22.7	0.6	322
LYNNWOOD	6.1	0.2	2.87	1.5	322
VANCOUVER	12.1	0.6	180.2	10.6	322
BROOKFIELD	10.7	0.3	20.67	4.9	322
GREEN BAY	46.9	2.4	463.75	1.7	322
MILWAUKEE	12.2	0.4	124.6	16.5	322

APPENDIX B

Risk Assessment Methodology for Sludge Incineration

United States
Environmental Protection
Agency

X

FINAL
ECAO-
March,

EPA

Research and Development

DEVELOPMENT OF RISK ASSESSMENT METHODOLOGY FOR MUNICIPAL SLUDGE INCINERATION

Prepared for

OFFICE OF WATER REGULATIONS
AND STANDARDS

Prepared by

Environmental Criteria and
Assessment Office
Cincinnati OH 45268

8- i

DISCLAIMER

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

DOCUMENT DEVELOPMENT

L. Fradkin, Document Manager
Environmental Criteria and Assessment Office
Office of Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

W.B. Peirano, Co-Document Manager
Environmental Criteria and Assessment Office
Office of Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

G. Crumpler
Wastewater Solids Criteria Branch
Office of Water Regulations and Standards
U.S. Environmental Protection Agency
Washington, DC 20460

T. Braverman, Technical Project Manager of Air Dispersion Modeling
Source-Receptor Analysis Branch
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

M. Dutsezina, Human Exposure Model (HEM) Pollutant Assessment Branch
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

R. McCarthur and G.E. Anderson, Air Modeling
Systems Applications Inc.
San Rafael, CA 94903

External Reviewers

Mr. A. Baturay
Carlson Associates Technical Services, Inc.
Rand Engineering
West Redding, CT

Mr. C.R. Brunner
Incinerator Systems
CH2M Hill Inc.
Reston, VA

Mr. R. Dykes
Radian Corporation
Research Triangle Park, NC

Dr. R.M. Gerstle, V.P.
PEI Associates
Cincinnati, OH

Dr. D. Johnson
Department of Environmental Health
University of Cincinnati Medical Center
Cincinnati, OH

Mr. W. Niessen
Camp Dresser and McKee, Inc.
Boston, MA

Dr. C.V. Pearson
Argonne National Laboratory
Argonne, IL

Dr. M. Radike
Department of Environmental Health
University of Cincinnati Medical Center
Cincinnati, OH

Dr. P.A. Vesiland
Department of Civil Engineering
Duke University
Durham, NC

Document Preparation

Technical Support Services Staff: Patricia A. Daunt, Bette L. Zwayer and Jacqueline Bohanon, Environmental Criteria and Assessment Office, Cincinnati

TABLE OF CONTENTS

Page

1. INTRODUCTION. 1-1

2. DEFINITION OF DISPOSAL PRACTICE 2-1

2.1. INCINERATION 2-4

2.1.1. Uniform Feed. 2-4
2.1.2. Burning Methods 2-6
2.1.3. Energy Recovery 2-14
2.1.4. Instrumentation and Control 2-14

2.2. AIR POLLUTION CONTROL. 2-15

3. IDENTIFICATION OF KEY PATHWAYS. 3-1

3.1. AIR EMISSIONS. 3-1
3.2. ASH RESIDUE. 3-3
3.3. SCRUBBER WATER 3-7

4. METHODOLOGY FOR AIR EMISSIONS PATHWAY 4-1

4.1. OVERVIEW OF METHOD 4-1
4.2. FATE AND TRANSPORT 4-2

4.2.1. POTW Incinerator Data Base. 4-2
4.2.2. Model Selection Criteria. 4-6
4.2.3. Facilities Selected 4-10
4.2.4. Modeling Long-Term Average Concentration Patterns. 4-12

5. EXPOSURE AND ASSESSMENT OF HEALTH EFFECTS 5-1

5.1. HUMAN EXPOSURE MODEL (HEM) 5-1

5.1.1. Exposure. 5-2
5.1.2. Inhalation Volume 5-2
5.1.3. Particle Size Distribution. 5-3
5.1.4. Contaminant Concentration 5-3
5.1.5. Model Description 5-3
5.1.6. HEM Estimation Scheme 5-3

5.2. HEALTH EFFECTS 5-6

5.2.1. Health Effects Data 5-6

6. EXAMPLE CALCULATION 6-1

6.1. STEP ONE 6-1
6.2. STEP TWO 6-3

7. REFERENCES. 7-1

LIST OF TABLES

No.	Title	Page
2-1	Distribution of Sludge Combustion Facilities by State and Type.	2-2
2-2	Operational Status of Various Types of Installations.	2-3
2-3	Distribution of Sludge Combustion Systems by Plant Size . . .	2-5
3-1	EP Toxicity Testing of Sludge Incinerator Ash	3-5
4-1	Major Assumptions for the Sludge Incineration Methodology . .	4-3
4-2	Air Pollution Control Systems by Furnace Type	4-9
4-3	Facility Coordinates, Stack Parmaeters and Building Dimensions of the Sewage Sludge Incinerator Plants.	4-11
4-4	Options Used in the ISCLT Modeling.	4-14
4-5	Options Used in the LONGZ Modeling.	4-17
4-6	Options Used in the COMPLEX I Modeling.	4-19
4-7	Ring Distances According to Facility Modeled.	4-22
4-8	Meteorological Input Data for ISCLT and LONGZ Models.	4-24
4-9	Mixing Height and Ambient Temperature Data According to Stability and Facility.	4-26
5-1	Daily Respiratory Volumes for "Reference" Individuals (Normal Individuals at Typical Activity Levels) and for Adults with Higher-than-Normal Respiratory Volume or Higher-than-Normal Activity Levels.	5-9
5-2	Illustrative Categorization of Evidence Based on Animal and Human Data.	5-15

LIST OF FIGURES

No.	Title	Page
1-1	Guidelines Derivation Procedure for Sludge Management	1-2
2-1	Cross Section of a Fluid Bed Furnace	2-7
2-2	Cross Section of a Typical Multiple Hearth Incinerator	2-10
2-3	Process Flow Diagram Infrared Incineration System	2-12
2-4	Cross-sectional View of a Venturi/Impingement-Tray Scrubber	2-17
3-1	Sludge Incineration Pathways	3-2
4-1	Distribution of Stack Heights for Sludge Incinerators	4-5
4-2	Distribution of Capacity for 127 Sludge Incineration Sites	4-7
4-3	Distribution of Stack Exit Gas Velocities for Sludge Incinerators	4-8
5-1	Reference Points for an Enumeration District/Block Group (ED/BG) Centroid	5-5
6-1	Criteria Derivation Approaches for Sludge Incineration	6-2

LIST OF ABBREVIATIONS

APC	Air pollution control
BG/ED	Block group/enumeration district
BOD	Biochemical oxygen demand
Btu	British thermal unit
BW	Body weight
COD	Chemical oxygen demand
ESP	Electrostatic precipitator
FB	Fluidized bed
GPM	Grams per minute
HEM	Human exposure model
I_a	Air inhalation rate
ISCLT	Industrial Source Complex Long-Term
MEI	Most-exposed individual
MEIM	Most-exposed individual methodology
MHF	Multiple hearth furnace
NSPS	New Source Performance Standards
PAH	Polynuclear aromatic hydrocarbons
PCB	Polychlorinated biphenyls
P-G	Pasquill-Gifford
POTW	Publicly-owned treatment works
q_1^*	Human cancer potency
RAC	Reference air concentration
RDF	Refuse-derived fuel
RE	Relative effectiveness
RfD_i	Reference dose for inhalation

LIST OF ABBREVIATIONS (cont.)

RL	Risk level
RMCL	Recommended maximum contaminant level
STAR	STability ARray
TBI	Total background intake
W.G.	Wet gas

1. INTRODUCTION

This is one of a series of reports that present methodologies for addressing the potential risks to humans from management practices with disposal or reuse of municipal sewage sludge. The management practices addressed by this series are land application (including distribution and marketing programs), landfilling, incineration and ocean disposal. In particular, these deal with reports for the evaluation of potential health and environmental risks from toxic chemicals that may be present in sludge. This document addresses risks from chemicals associated with sludge incineration practices.

These proposed risk assessment procedures are structured to allow calculation of technical guidelines for sludge disposal/reuse options based on the potential for health or environmental impacts. The guidelines may address required management practices (such as site design or process control specifications), limits on sludge disposal rates or on toxic chemical concentrations in the sludge or both.

As illustrated in Figure 1-1, the guidelines derivation process begins by defining the management practice. This definition, presented in Chapter 2, is an important starting point for determining the application limits of the methodology and the exposure pathways that may be of concern. However, a final definition will not be possible until the methodology has been applied, since the methodology itself will help to define acceptable practice, as will be discussed.

Exposure pathways are migration routes of chemicals from (or within) the disposal/reuse site to humans. Each exposure pathway may lead to the exposure of one or many individuals. These individuals will differ in their

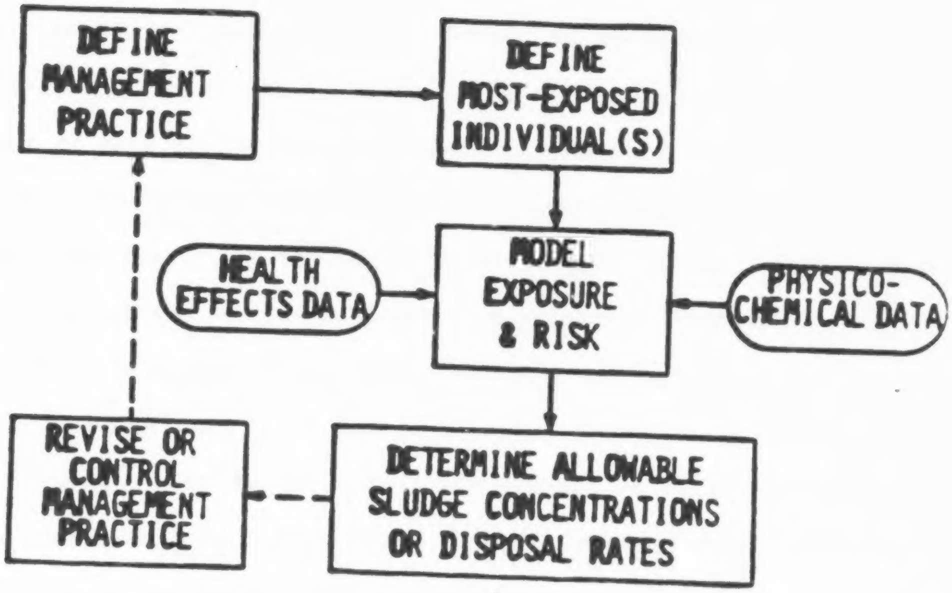

DEFINE MANAGEMENT PRACTICE
DEFINE MOST-EXPOSED INDIVIDUAL(S)
HEALTH EFFECTS DATA
MODEL EXPOSURE & RISK
PHYSICO-CHEMICAL DATA
REVISE OR CONTROL MANAGEMENT PRACTICE
DETERMINE ALLOWABLE SLUDGE CONCENTRATIONS OR DISPOSAL RATES

FIGURE 1-1

Guidelines Derivation Procedure for Sludge Management degree of exposure and in their susceptibility to effects from a given exposure. An ideal way to assess risk is to define the full spectrum of potential levels of risk and the number of individuals at each level, thus quantifying the total or aggregate risk for a given exposure pathway.

However, these methodologies are not designed to define total risk in most cases, for the following reasons. First, it is difficult to estimate the total distribution of risks, since to do so requires knowledge of the distributions of each of the numerous parameters involved in the risk calculations, and requires the modeling of actual or hypothetical population distributions and habits in the vicinity of disposal sites. Such a task exceeds the scope of the present methodology development effort.

Second, while knowledge of the total exposure may be useful for certain types of decision-making, it is not necessarily required for establishing criteria to protect human health. Criteria are set so as to be reasonably protective of all individuals, including those at greatest risk. As long as the risk assessment procedures can reasonably estimate the risk to these individuals, then the quantification of lesser risks experienced by other individuals is not required.

The drawback, however, of examining only a maximum-risk situation is that the true likelihood of such a situation occurring will be diminished. The compounding of worst-case assumptions may lead to unrealistic results. Therefore, the key to effective use of this methodology is a careful and systematic examination of the effects of varying each of the parameters (i.e., performing sensitivity analyses), using estimates of central tendency and upper-limit values in order to gain an appreciation for the variability of the result. This appreciation must then be coupled with a policy decision regarding how restrictively to define the individual at risk. Based on these considerations, parameter values can be assigned that ensure the desired degree of protection. Uniform application of these procedures for all sludge management practices will further ensure that criteria for each practice are comparably protective of human health and the environment.

Risk assessment for a given chemical combines the elements of exposure assessment and dose-response assessment for each chemical. Procedures for dose-response assessment, consisting of methods for estimating toxicity thresholds or cancer potency, are already established in the Agency and are geared toward protection of sensitive individuals. Although additional work is needed to improve these procedures, the focus of the present methodologies is to characterize the potential human or environmental exposures resulting from each sludge management practice. As explained previously, exposure is quantified for a "most-exposed individual," or MEI. The definition of the MEI will vary with each pathway; for some pathways the MEI may be a plant or animal rather than a human. Chapter 3 of each methodology will enumerate the exposure pathways and will define the MEI in qualitative terms; i.e., for the inhalation pathway, the MEI is a person residing in the vicinity of the incinerator.

The remaining chapters explain the calculation methods and data requirements for conducting the risk assessments for each pathway. Risk assessments ordinarily proceed from source to receptor. That is, the source is first characterized (usually based on an existing practice), and contaminant movement away from the source is then modeled to estimate the degree of exposure to the receptor, or MEI. Health effects are then predicted based on the estimated exposure. The calculation of criteria, however, involves a reversal of this process. That is, an allowable exposure, or an exposure that is not necessarily allowable but corresponds to a given level of risk, is defined based on health effects data. Based on this exposure level, the transport calculations are operated in reverse to determine the corresponding source definition. In this case, the resulting source definition is a combination of management practices and sludge characteristics, which constitute the criteria. Changes in the definition of the management practice can result in changes in sludge characteristics while still complying with the desired health goals. Therefore, Figure 1-1 is shown as a circular process, where management practices can be redefined based on the calculation results, if necessary.

These methods may be used to derive criteria that are either nationally applicable or site-specific. To derive criteria that are reasonably protective in all situations nationwide, parameter choices must be relatively conservative, i.e., they must assume a reasonable worst case. For site-specific applications, however, the same calculations may be used, but actual rather than assumed values for site-design and other environmental parameters must be used. In some cases, experimental or analytical procedures conducted at a given location can be used to further improve the accuracy of the result and to demonstrate that a desired level of protection will be achieved.

2. DEFINITION OF DISPOSAL PRACTICE

Sludge incineration involves the combustion of sludge within a mechanically controlled environment. Incineration is a treatment method used before disposal or reuse of the ash. Because incineration drastically reduces the volume and mass of sludge, it has been traditionally considered a disposal method similar to landfilling and ocean dumping. Land applications (including distribution and marketing of sludge) are considered use options, since in these cases beneficial properties of sludge are utilized.

Currently, only three types of incineration technology are employed for dedicated sludge combustion in the United States as listed below:

1. Multiple hearth furnace (MHF);
2. Fluidized bed (FB) furnace; and
3. Infrared electric furnace.

In addition, sludge has been coincinerated with municipal solid waste in mass burning incinerators. However, for the purposes of developing standards and management practices, this methodology will not consider coincineration of sludge with other wastes, but will concentrate on dedicated sludge incineration that uses fossil fuels for auxiliary firing.

Table 2-1 presents the distribution of sludge combustion types by state and indicates the number of facilities that are operational. The facilities are located primarily on the East Coast and in the Midwest. As can be seen from Table 2-1, most of the plants are in nine states and MHFs are the dominant type (73%). FB furnaces represent 20% of the total.

Table 2-2 shows that 58% of the incineration facilities are operational. Of the 156 operating units, 120 or 80% are MHF and 25 or 16% are FB furnaces.

TABLE 2-1

Distribution of Sludge Combustion Facilities by State and Type*

State	Multiple-Hearth		Fluidized-Bed		Electric (Infrared)		Rotary Kiln		Cocombustion Refuse-Sludge	
	Total	Operating	Total	Operating	Total	Operating	Total	Operating	Total	Operating
Alaska	2	1			2	1				
Arkansas	1	0	2	1						
California	9	5	5	2			1	1		
Colorado	1	0								
Connecticut	13	8	4	1					1	1
Florida	2	1								
Georgia	4	4			2	2			1	1
Hawaii	2	1								
Illinois	4	1								
Indiana	2	1	1	1						
Iowa	2	2	1	1						
Kansas	2	2	2	2						
Kentucky	2	0			1	1				
Louisiana	3	3	1	1						
Maryland	5	2	1	1						
Massachusetts	9	4	2	0			1	0		
Michigan	20	10	2	1	1	0				
Minnesota	2	2								
Missouri	2	1	3	0						
Nebraska			1	1						
Nevada	2	0	1	0						
New Hampshire	3	3								
New Jersey	11	10	6	5						
New York	30	20	10	3	1	1			1	0
North Carolina	2	0	2	1						
Ohio	12	10	2	0						
Oklahoma	2	0								
Oregon	1	1								
Pennsylvania	17	9	5	2						
Rhode Island	3	0								
South Carolina	2	2								
Tennessee	4	3	1	1						
Texas	1	0			4	2				
Virginia	10	9	1	0						
Washington	1	1	1	1	1	1				
West Virginia	2	1								
Wisconsin	5	2								
Puerto Rico	1	1								
TOTALS	196	120	54	25	12	8	2	1	4	2

*Source: U.S. EPA, 1985a

TABLE 2-2

Operational Status of Various Types of Installations*

Type of Combustor at Facility	Number of Facilities	Number that are Operating (%)
Multiple-hearth furnace	196	120 (61)
Fluidized-bed furnace	54	25 (46)
Electric infrared furnace	12	8 (67)
Rotary kiln	2	1 (50)
Cocombustion with refuse	4	2 (50)
TOTALS	268	156 (58)

*Source: U.S. EPA, 1985a

Table 2-3 shows the distribution of sludge incineration systems by plant size, expressed as flow-treated. While most of the plants are 438 ℓ/sec (L/S) (10 mgd) or larger, a significant number are in the 43.8-219 L/S (1-5 mgd) range, but the ratio of operating plants to total plants goes up as the plant size increases. Those facilities noted to be nonoperational are either no longer in service, still in construction or startup, being retrofitted, or used seasonally. A list of locations, as of early 1984, of 206 existing sludge incinerators handling municipal sludge solids from primary, secondary and tertiary treatment may be found in U.S. EPA (1985a).

2.1. INCINERATION

2.1.1. **Uniform Feed.** Uniform feed of sludge is critical to the satisfactory operation of incineration systems. Realization of uniform feed requires good control of sludge thickening, blending, sludge age control and pumping before dewatering. If these tasks are managed and maintained properly and the dewatering equipment is operated correctly, the output of the dewatering equipment will be uniform.

If the dewatering equipment operates on a batch basis (such as the plate and frame press) or is subject to frequent upsets or outages, a sludge cake storage and uniform feed device (such as a silo or hopper with a flight conveyor floor and a weigh feeder) is required.

An incinerator must have uniform feed; a variation of ±10% of the selected feed rate over 8 hours is acceptable. Uniform feed assures stable operation and prevents upsets that could lead to excessive emissions. Each incinerator should have a dedicated weigh belt feeder, which is calibrated weekly, so that the sludge feed rate can be monitored by the operator on a strip chart recorder or computer for recording historical trends.

TABLE 2-3

Distribution of Sludge Combustion Systems by Plant Size[a]

	Flow (mgd)[b]					
	0-1	1.1-5	5.1-10	10.1-25	25.1-50	50.1+[c]
Systems in operation	5	28	18	60	23	17
Systems not operating	9	22	18	12	5	5
TOTALS	14	50	36	72	28	22
Percentage in operation	36	56	50	83	82	77

[a] Source: U.S. EPA, 1985a

[b] mgd = 43.8 L/S

[c] In the category of plants larger than 50 mgd, virtually all of these have multiple units, so a count based on units installed would possibly show the rising trend continuing.

For large treatment facilities with multiple dewatering units and incinerators, the materials handling equipment (including conveyor belts and screw conveyors) must distribute the total sludge quantity dewatered at a uniform feed rate to each incinerator. For small facilities with one or two dewatering units and one incinerator, all sludge generated is usually dedicated to a particular furnace. These smaller plants present special challenges to the goal of maintaining uniform feed.

Most operating personnel recognize the need for uniform feed to incinerators. However, ~10-20% of U.S. incinerators do not receive uniform feed because of problems with equipment design, poor sludge quality or inadequate process control.

Nonuniform feed causes incinerator upsets, unstable furnace temperatures, and subsequent increases in stack emissions. Nonuniform feed also frustrates operating personnel because of the necessity of making frequent operating changes and may result in flare-ups and increased incinerator hearth maintenance in multiple hearth furnaces.

The cost of maintaining uniform feed is minimal if the sludge thickening, conditioning, dewatering, storing and conveying facilities are designed and operated properly. Importantly, these qualities depend upon a visible commitment of plant management to good uniform feed. In any event, appropriate operator training, process control and preventive maintenance are required.

2.1.2. Burning Methods.

2.1.2.1. **FLUIDIZED BED INCINERATION (FB)** -- The FB incinerator is a plug-flow device (Figure 2-1). An FB operates ≥30% excess air and normally with a bed temperature of 1400-1600°F. The importance of this basic process

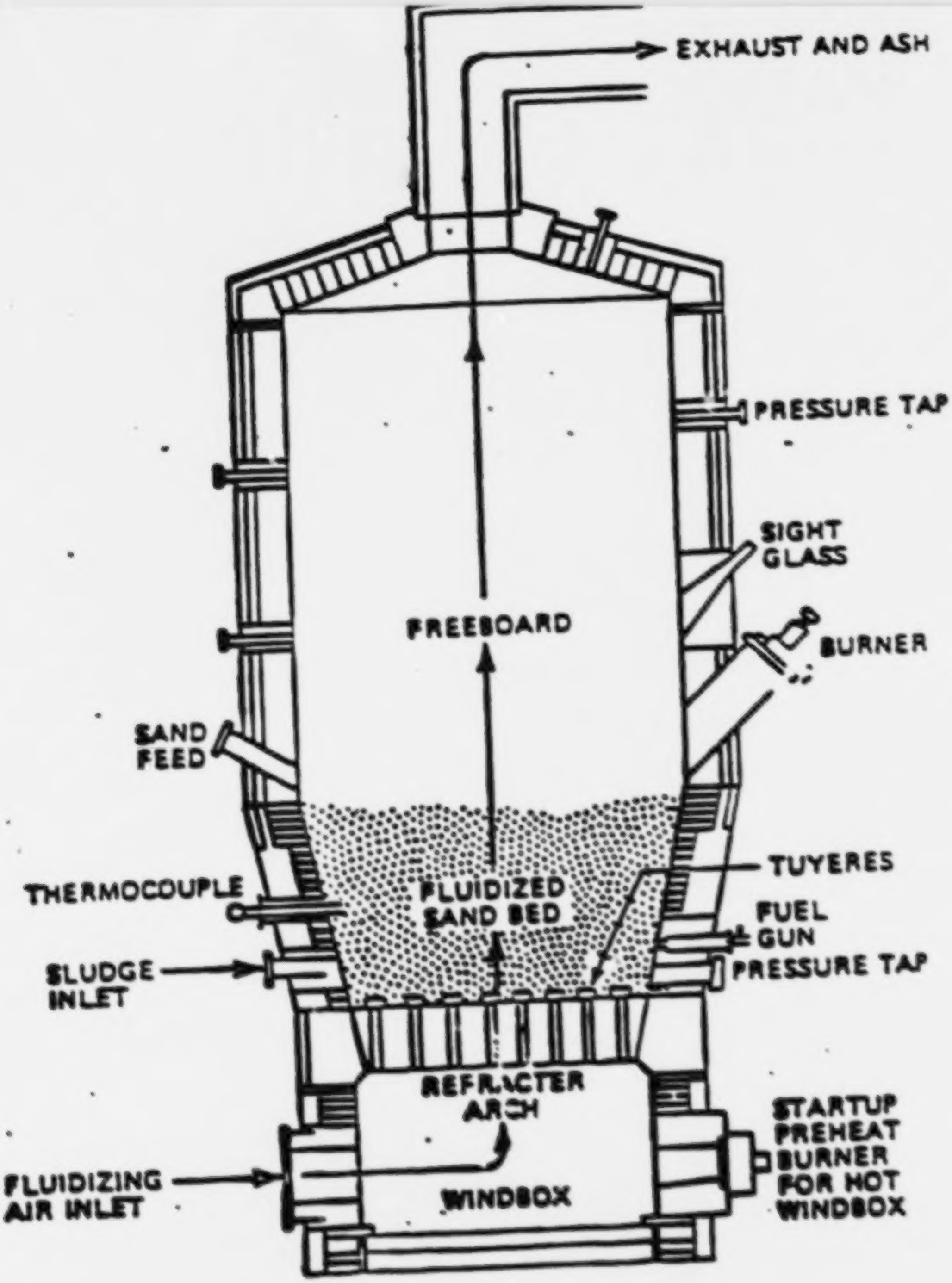

EXHAUST AND ASH
PRESSURE TAP
SIGHT GLASS
FREEBOARD
BURNER
SAND FEED
TUYERES
THERMOCOUPLE
FLUIDIZED SAND BED
FUEL GUN
SLUDGE INLET
PRESSURE TAP
REFRACTER ARCH
STARTUP PREHEAT BURNER FOR HOT WINDBOX
FLUIDIZING AIR INLET
WINDBOX

FIGURE 2-1

Cross Section of a Fluid Bed Furnace

~~process~~ feature became critical in the 1970s when rapidly escalating supplementary fuel costs made the burning of 15-18% solids sludge cake prohibitively expensive. The development and validation of the hot windbox design has made FB technology economically competitive; although dewatering to better than 30% solids is necessary to avoid excessive fuel use. However, there are still many more MHFs in the United States than FB systems and only a operating few hot windbox systems.

The FB system provides an excellent environment for the destruction of organic chemicals because of its excellent mixing at any cross-section, its uniform temperature, and its long residence time. Further, its inherent limitation to working temperatures below 1700°F, and preferably to 1500°F, limits the sublimation-condensation enrichment of the hard-to-collect fine particulate matter of the important heavy metals mercury, cadmium, lead, zinc and silver. On the negative side, the FB inherently carries off 100% of the ash content of the feed sludge, any unburned combustible matter, and any sand attrition in the flue gases exiting the furnace. Thus, the demands placed on the air pollution control (APC) system are high; such units regularly meet the particulate emission limits in the United States and meet considerably more stringent limits in European installations.

Although no definitive data are available, some vendors claim that organic emissions are minimized if sludge is fed to the bed as shown in Figure 2-1 rather than dropped through the freeboard space. Also, the use of overfire air jets in the freeboard improves the burnout of greases and volatilized organics.

At the Hyperion plant in Los Angeles that is based on an extensive piloting program, a multistage FB system is under construction for incinerating dried sewage sludge. In this facility, staged combustion is used to limit the degree of combustion in the first bed to less than stoichiometric. This reduces NO_x generation significantly since it minimizes the peak temperature. This also results in a reduction in metals emission. Presumably, the final stage will not produce excessive carbon monoxide or unburned hydrocarbon emissions.

2.1.2.2. **MULTIPLE HEARTH FURNACE (MHF)** -- An MHF is capable of incinerating dewatered sewage sludge with a solids content between 16 and 50% (Figure 2-2). Concentrated skimmings or scum with a solids concentration between 25 and 60% can be coincinerated in furnaces in quantities of 1-3 gallons per minute (GPM).

The excess air typically used for incinerating sludge is usually 75-150% with a furnace incinerating drier sludges and a top-hearth exhaust gas temperature of 700-1600°F (371-871°C). Some additional residence time should be provided after the point of sludge introduction to ensure burnout of organic vapors. The excess air requirement for auxiliary fuel is usually 10-20% as with premix (gas) or good atomization (oil). Some of the MHFs are equipped with afterburners for raising off-gas temperature to 1400 or 1500°F for complete combustion of unburned hydrocarbons. The burning hearth temperature should be controlled 200-300°F below the ash fusion temperature to prevent slagging and, thereby, to improve incinerator operational availability.

2.1.2.3. **ELECTRIC INFRARED FURNACE** -- The electric infrared furnace represents a relatively new technological approach to the problem of sludge incineration. The first such unit was put into operation in Richardson, Texas in 1975. Since that time, a number of installations have been constructed and others are in various stages of design. The furnace is

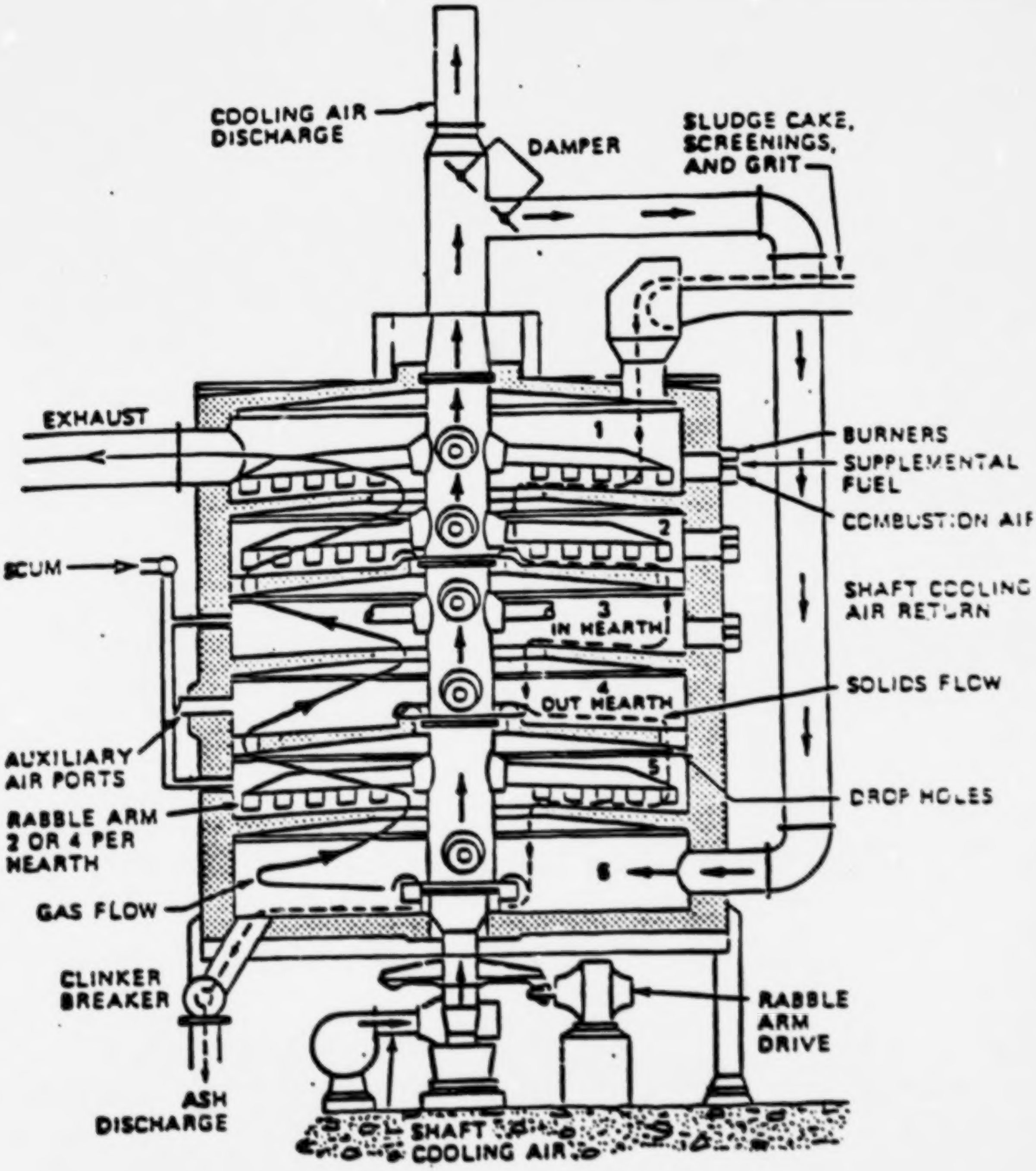

COOLING AIR DISCHARGE
DAMPER
SLUDGE CAKE, SCREENINGS, AND GRIT
EXHAUST
1
BURNERS
SUPPLEMENTAL FUEL
2
COMBUSTION AIR
SCUM
3
IN HEARTH
SHAFT COOLING AIR RETURN
4
OUT HEARTH
SOLIDS FLOW
AUXILIARY AIR PORTS
5
DROP HOLES
RABBLE ARM 2 OR 4 PER HEARTH
6
GAS FLOW
CLINKER BREAKER
RABBLE ARM DRIVE
ASH DISCHARGE
SHAFT COOLING AIR

FIGURE 2-2

Cross Section of a Typical Multiple Hearth Incinerator horizontally oriented and consists of an insulated enclosure through which sludge is transported on a continuous, woven wire conveyor belt. The furnace is comprised of a steel shell, factory-lined with a thermal shock resistant ceramic fiber blanket insulation system and containing support rollers for the conveyor belt.

Sewage sludge is fed into the unit through a feed hopper. It drops onto the conveyor belt and is leveled by means of an internal roller into a layer ~1 inch thick, spanning the width of the belt. The sludge layer then moves under infrared heating elements which provide supplementary energy (if required) to effect the drying and incineration processes. The resulting ash is discharged from the end of the furnace into the ash handling system. Combustion air is introduced at the discharge end of the belt. It is often preheated with an external recuperating exhaust heat exchanger. The air picks up heat from the hot burned sludge as the sludge and air travel countercurrent to each other.

The conveyor belt is a continuous woven wire mesh of steel alloy that will withstand the 1300-1500°F temperature encountered within the furnace. The refractory is not brick but ceramic felt, as shown in Figure 2-3. It does not have a high capacity for holding heat and therefore the furnace can be started up from cold condition relatively quickly.

Because the primary heat transfer mechanism utilized in the infrared furnace is radiant, combustion rates can be achieved without rabbling or plowing of the sludge layer. Therefore, fly ash generation is minimized and the control of particulate emissions is simplified as compared with multiple hearth and fluid bed furnaces.

Complete combustion can be achieved in the infrared furnace with excess air levels as low as 10-20%. This process efficiency is attributed to

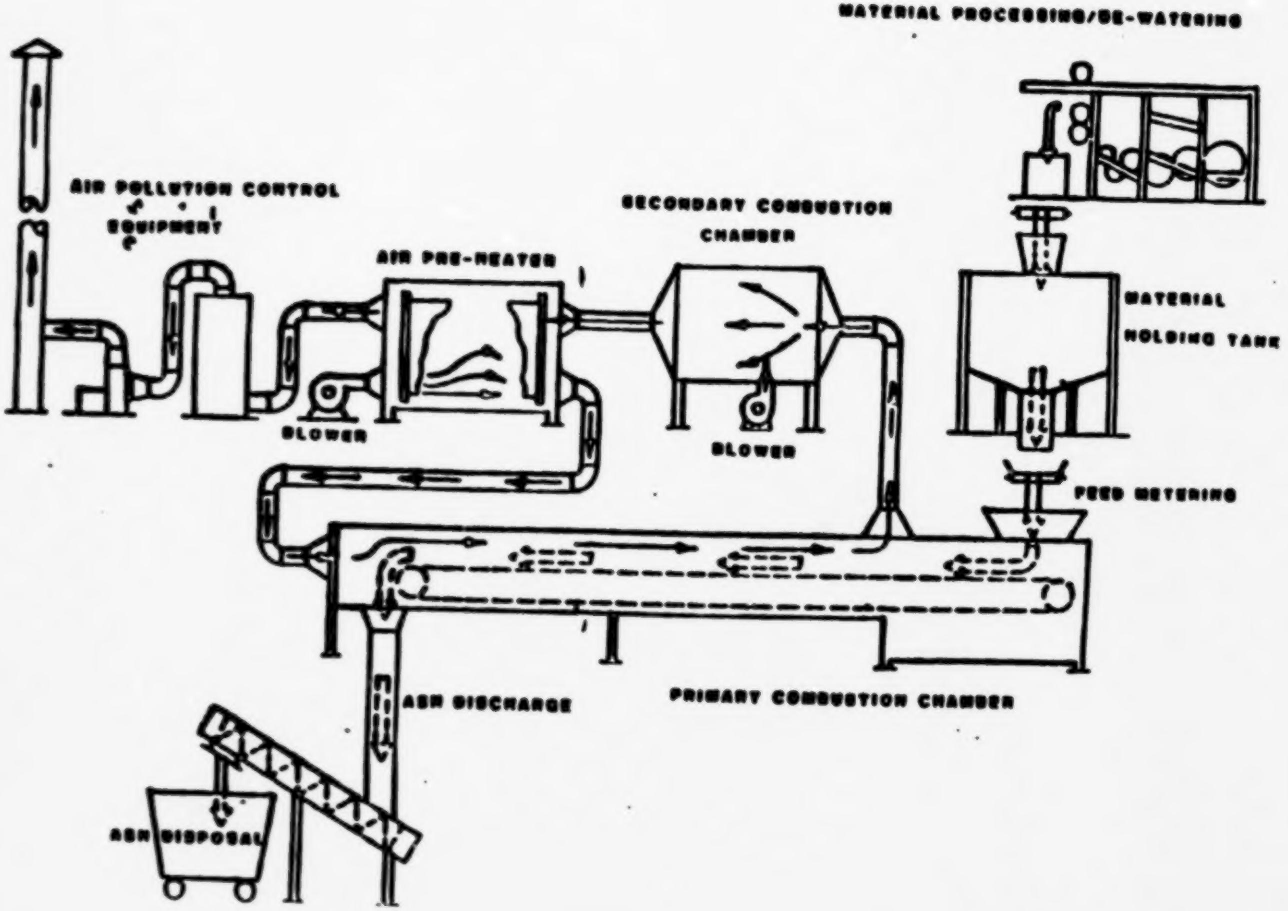

MATERIAL PROCESSING/DE-WATERING
AIR POLLUTION CONTROL EQUIPMENT
SECONDARY COMBUSTION CHAMBER
AIR PRE-HEATER
MATERIAL HOLDING TANK
BLOWER
BLOWER
FEED METERING
ASH DISCHARGE
PRIMARY COMBUSTION CHAMBER
ASH DISPOSAL

FIGURE 2-3

Process Flow Diagram Infrared Incineration System several factors. First, the design of the furnace is such that uncontrolled sources of excess air are eliminated; second, the flow of combustion air is closely regulated and directed down the channel formed between the belt and the heating elements overhead and; third, there are no gaseous products of combustion of supplementary fuel to dilute the supply of combustion air. This ability to operate at low excess air levels contributes to a further reduction in the size, complexity and energy requirements of the exhaust gas scrubbing equipment required for the electric infrared furnace. Usually a low energy gas scrubber, such as a cyclonic scrubber is all that is required to elevate exhaust gases.

The system is divided into several temperature control zones for the incineration process. These zones are maintained at predetermined temperatures by closed-loop control. Temperatures are sensed by thermocouples, compared with the setpoint, and the input power to the infrared heating elements adjusted upward or downward accordingly. Control temperatures range from 1400°F in the drying zones to 1700°F in the combustion zones. The flow of air for sludge combustion is also controlled by a closed-loop process. The residual oxygen content in the exhaust stream is detected continuously and compared with a setpoint value. The flow of combustion air is then regulated to maintain the setpoint value. In the event that a high energy sludge is being processed, additional excess air may be utilized to limit exhaust temperatures to the 1200-1400°F range. The throughput of the system can be controlled by adjusting the speed of the internal conveyor belt. This adjustment is accomplished from the control panel and can be also used to adjust retention time in order to compensate for different sludge feeds. To date, infrared furnaces have been used in smaller applications where its operating flexibility provides an advantage over traditionally larger MHF or FB systems. Because of its ceramic fiber blanket insulation system, it is well suited for intermittent operation. This insulation system is not subject to the limitations on thermal cycling that are associated with the traditional types of solid refractory materials. Start-up times of 1-1.5 hours are normal, and shutdown is accomplished by pressing a single "System Stop" button and leaving the furnace unattended until such time as it again needs to be operated.

2.1.3. Energy Recovery. Many new sewage sludge incineration installations include energy recovery equipment. Most of the recently constructed FB incinerators are equipped with air preheaters where air for fluidization and combustion is preheated to as much as 1000°F. Some recent FB incineration systems also include waste heat recovery boilers with steam generation for driving rotating ancillary equipment, or providing building heat or power generation or both. Energy recovery is prevalent in European facilities.

Inclusion of energy recovery equipment into the sludge incineration system results in the reduction of the amount of uncontrolled particulate emission to the scrubbers since a small fraction of the particulates in the energy recovery equipment settle out in the hopper bottoms.

The reduced gas temperature exiting from the boiler permits the use of temperature sensitive air pollution control devices such as fabric filters or electrostatic precipitators, which could not be used if energy recovery were not used.

2.1.4. Instrumentation and Control. Reliable, easy to use and maintain instrumentation can reduce the potential for emission upsets because the operator can control the incineration process more efficiently. At present, many incinerators are operated without the benefit of complete instrumentation. Operation is good if the incinerators are receiving nonuniform sludge feed.

In the last 10 years, many MHFs have been upgraded with automatic hearth temperature controls. Similar controls are available for FB units. Incinerators burning sludge autogenously (without significant fossil fuel use) benefit greatly from automatic temperature control since it ensures sufficient secondary combustion air (cooling) in order to maintain proper hearth temperatures. In addition, operators are more proficient in reducing fuel and smoke by using a continuous oxygen and stack opacity analyzers. The use of these instruments requires management support and commitment to frequent and competent instrumentation maintenance and a careful review of the data to ensure proper operation. For incinerators built after 1973, there is a regulatory requirement to install, calibrate, maintain and operate a flow measuring device (Federal Register, 1974).

The use of on-line total carbon and hydrocarbon analyzers are still in the research and development stage. Such instruments may improve the operators ability to monitor and control the incineration process. However, additional research and development and field evaluations are required to determine usefulness and reliability of these on-line instruments before they can be used for operational control.

2.2. AIR POLLUTION CONTROL

Virtually all incinerators currently operating in the United States are equipped with wet scrubbers for emission control. A wide variety of wet scrubbers are in use including fixed and variable throat Venturi impingement plates and cyclonic scrubbers. Most sludge incinerators, particularly those built in the last 10 years, are equipped with variable throat Venturi scrubber units and an impingement subcooling tray separator. Over 70% of the incinerators installed since 1978 are equipped with combination Venturi/impingement tray scrubbers. There are no incinerators in the United States equipped with ESPs. Several European FB incinerators use ESPs and achieve particulate emissions less than the United States NSPS of 0.65 g/kg (1.3 lb/ton).

Almost all MHFs are equipped with wet scrubbers. The most recent installations are equipped with Venturi scrubbers and impingement plate subcoolers (Figure 2-4). Venturi scrubbers are capable of meeting the required emissions discharge rate of 1.3 lb particulates/ton dry sludge incinerated at an average pressure drop of 30 inches W.G. across the scrubber. Most of the subcoolers are designed for cooling scrubbed gases to 100-120°F.

The pressure drops at which these scrubbers are operated varies widely among different facilities. Pressure drops in the range of 4 inches W.G. to over 40 inches W.G. have been reported. In general, the operating pressure drops have increased since promulgation of the NSPS in 1973. Most incinerators installed in the past 8 years are equipped with wet scrubbers operating at pressure drops of about 30 inches W.G. However, poor correlation between scrubber pressure drop and particulate emissions have been found.

The performance of wet scrubbers in reducing emissions of solid-phase constituents is influenced primarily by the pressure drop across the central device. As the pressure drop increases, more solid-phase particles are removed from the gas stream. However, a review of U.S. incinerator emission data shows no general correlations established between scrubber pressure drop and particulate emissions, because the particle size distribution and total loading is so variable between different plants that the patterns in the data become confused. In other words, operating a wet scrubber at a

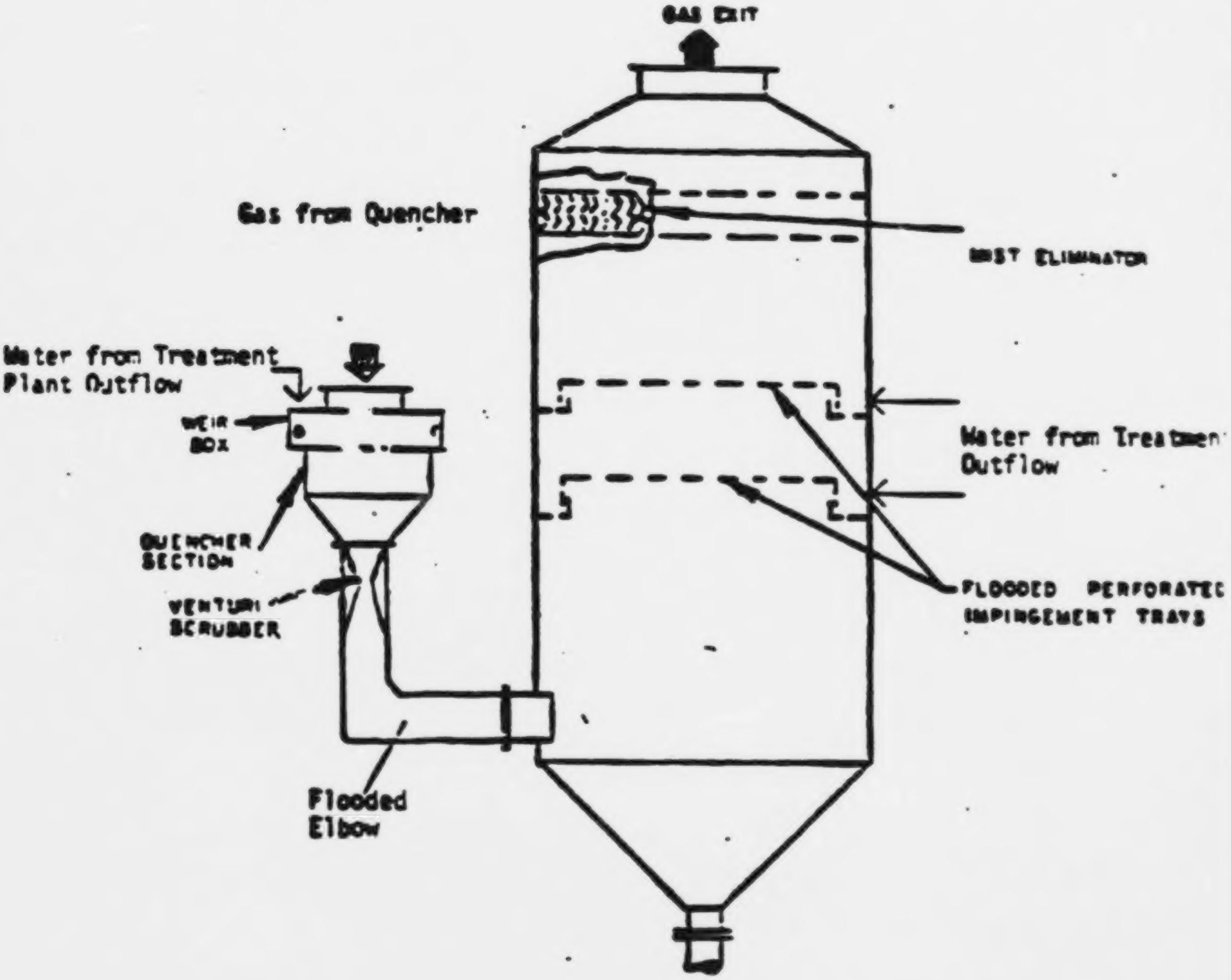

GAS EXIT
Gas from Quencher
MIST ELIMINATOR
Water from Treatment Plant Outflow
WEIR BOX
QUENCHER SECTION
VENTURI SCRUBBER
Flooded Elbow
Water from Treatmen
Outflow
FLOODED PERFORATE
IMPINGEMENT TRAYS

FIGURE 2-4

Cross-sectional View of a Venturi/Impingement-Tray Scrubber given pressure drop does not guarantee that any specific emission rate will be achieved. For an individual incinerator, solid-phase emissions will decrease with increasing pressure drop. But the magnitude of this decrease will vary widely among different incinerators and different operating conditions.

Wet scrubbers are not as effective in reducing emissions of solid particles with mean diameters of <1 μm and at removing grease vapors. The effectiveness decreases as pressure decreases.

To some extent, wet scrubbers also reduce emissions of gaseous species. The major operating factor affecting performance in reducing gaseous emissions is the liquid-to-gas ratio. Wet scrubbers typically reduce emissions of SO_2 by ~50%. Wet scrubbers also reduce soluble gas emissions such as hydrogen chloride and hydrogen fluoride, and decrease condensable hydrocarbon emissions.

3. IDENTIFICATION OF KEY PATHWAYS

The air emissions, ash residue (wet or dry) and scrubber water represent the major pathways for pollutants to enter the environment and potentially impact human health. Figure 3-1 is a schematic diagram that identifies these pathways and their potential routes of human exposure.

3.1. AIR EMISSIONS

One of the pollutant pathways identified in Figure 3-1 begins with the particulate and gaseous emissions generated by the combustion process. These emissions pass through a wet scrubbing air pollution control system that reduces the particulate and gaseous pollutant concentrations in the exhaust gas. There are several regulatory programs that exercise control over air pollutants emitted from sludge incineration processes.

The EPA has established ambient air standards for sulfur dioxide (SO_2), total suspended particulates (TSP), carbon monoxide (CO), ozone (O_3), nitrogen dioxide (NO_2) and lead (Pb) as mandated by the Clean Air Act Amendments of 1970 (P.L. 91-604). Depending on size, level of emissions, and the ambient pollutant concentrations in the surrounding community, a new facility or a modification to an existing facility must undergo a New Source Review (NSR) or comply with the Prevention of Significant Deterioration (PSD) regulations before receiving a permit to construct. These preconstruction requirements assure that the ambient air concentrations defined by the National Ambient Air Quality Standards (NAAQS) will not exceed levels established to protect public health and welfare and, if applicable, will not exceed the allowable increment defined in the PSD review process.

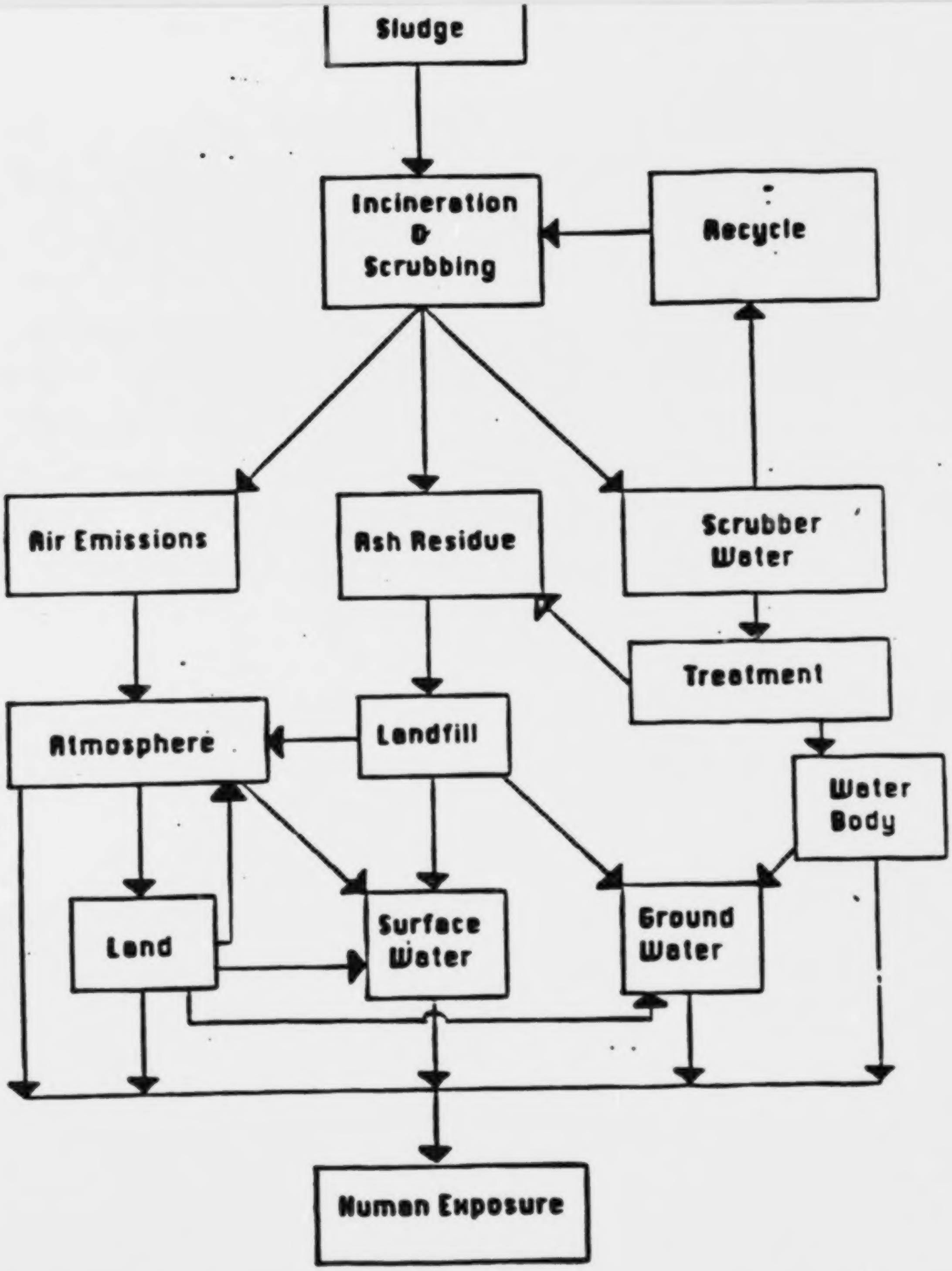

Sludge
Incineration & Scrubbing
Recycle
Air Emissions
Ash Residue
Scrubber Water
Treatment
Atmosphere
Landfill
Water Body
Land
Surface Water
Ground Water
Human Exposure

FIGURE 3-1

Sludge Incineration Pathways

For mercury, the National Emission Standards for Hazardous Air Pollutants (NESHAPs) establish an emission limit of 3200 g/day. State and local regulations may impose additional standards or more stringent requirements than those defined above.

Sludge incinerator emission limits are also established through New Source Performance Standards (40 CFR Part 60, Subpart O) that must be met for particulates [0.65 mg/kg (1.3 lb/ton) of particulate emitted per ton of dry solid sludges fired]. In addition, any emissions that equal or exceed 20% opacity are prohibited.

Airborne contaminants can impact several environmental media (see Figure 3-1). The most direct route of human exposure is through direct inhalation of particulate and gaseous emissions. Deposition of airborne particulates on land or in water bodies is a potential concern. Future work will assess this route of human exposure.

3.2. ASH RESIDUE

Municipal sludge incineration in well-operated facilities produces an odorless ash weighing between 30 and 60% of the weight of the original sludge on a dry basis. In the FB system, all ash is carried out the top of the chamber with the combustion gases. Most of the ash is removed from the combustion gas stream by a scrubber. In well-operated facilities, the resulting ash is completely burned out and, therefore, is not sooty or tacky. In an MHF system, most of the ash exits through the bottom of the furnace. Ash handling in this system is either wet (for use in slurry pipelines) or dry, although the ash is generally wetted for dust control before ultimate disposal.

Municipal wastewater plants in the United States generate ~72 million dry tons of sludge each year. Approximately 2 million tons of this are incinerated resulting in ~700,000 tons of ash that must finally be disposed of in an environmentally compatible manner.

Both dry and wet ash handling systems are currently in use. Dry ash handling, which applies principally to MHFs, is best when the ultimate disposal site is remote from the plant and when a time lag may occur between generation and shipping. Wet ash handling is most likely to be chosen when a lagooning site is available on or near the plant property. Wet ash handling is essentially the only method for an FB system when wet scrubbers are employed, because all of the ash is blown out of the combustor and caught in the scrubber. The result is a fairly low ash concentration compared with the slurry from an MHF wet system. The FB ash slurry is usually thickened in a tank and may also be dewatered on a filter before it is shipped to the disposal site. Ash can usually be handled by standard earth-moving equipment at the landfill site or in the lagoon cleanout process.

Trace elements found in sludge ash include silver, cadmium, cobalt, chromium, copper, mercury, nickel, lead and zinc. To this list are often added the metalloids, arsenic and selenium, and from the alkaline earth group, barium and beryllium. Using these elements as a reference base, a search of the literature found various tabulations of bulk trace element concentrations for different sludge ashes. Extraction procedure (EP) toxicity test data on sludge incinerator ash are presented in Table 3-1.

Strict comparisons among the values listed in Table 3-1 are not advisable because of the individual variations in sampling procedures, digestion techniques and analytical methods.

TABLE 3-1

EP Toxicity Testing of Sludge Incinerator Ash[a]
(mg/ℓ)

Location	Type of Incinerator	Arsenic	Cadmium	Chromium	Nickel	Lead
Detroit, MI	MHF	0.03	0.06	0.06	0.71	0.16
Green Bay, WI	MHF	0.001	0.03	0.45	35.95	0.08
Independence, MO	MHF	0.01	0.45	0.06	0.37	0.09
Indianapolis, IN	MHF	0.03	0.11	0.03	0.16	0.18
Parsippany, NJ	MHF	0.02	0.02	0.03	17.26	0.10
Port Huron, MI	FB	0.001	0.02	0.03	39.30	0.07
RCRA EP Toxicity Limits		5.0	1.0	5.0	35.00[b]	5.0

[a] Source: Adapted from U.S. EPA, 1984b

[b] This value is from personal communication with J.A. Poppipi, Office of Solid Waste.

In spite of these variations, it is possible to gain an acceptable evaluation of elemental concentration ranges in sludge ash. Several aspects of the data are worth expanding upon. Inspection of data on metals in raw and digested sludge (on a wt/wt basis) indicates the concentration effect for all metals measured in sludge ash (except mercury) is close to a 4-fold increase, as would be expected for municipal sludges with ~25% fixed solids. Mercury and selenium compounds are, of course, quite volatile even at relatively low temperatures.

New data

Wells et al. (1979) studied stack emissions from a sludge incinerator and reported the presence of organics such as ethyl and methyl ethyl benzene, toluene, styrene and other aromatic compounds, as well as saturated and unsaturated hydrocarbons. Organics occurring in sludge incinerated ash can also include chlorinated hydrocarbons and polynuclear aromatic hydrocarbons.

While Furr et al. (1979) found PCBs in municipal sewage sludges, neither Furr et al. (1979) nor Farrell and Salotto (1973) detected PCBs in sludge ash. However, Farrell and Salotto (1973) proposed that the disappearance of PCBs was not completely due to thermal decomposition but also to the adsorption of volatilized condensates onto particulates that escaped collection and were emitted from the incinerator stack.

Based on U.S. EPA-conducted tests of sludge and incinerator ash from 10 different cities (see Table 3-1), most incinerator ash should be acceptable for disposal without requiring special Subtitle C standards under the Resource Conservation and Recovery Act (RCRA) (U.S. EPA, 1984b). All sludge incinerator ashes passed the regulatory threshold standards specified in the EP toxicity test in 40 CFR 261.24.

If a sludge incinerator ash should fail the U.S. EPA toxicity test, then the ash would become a hazardous waste. The ash would then be subject to RCRA manifesting requirements and would be disposed of in a permitted secure landfill.

3.3. SCRUBBER WATER

Scrubber water is influenced by a number of factors including the following:

- The type of incineration process;
- The temperature of combustion'
- The characteristics of the feed sludge; and
- The scrubber efficiency.

Incinerator scrubber water generally contains only a small amount of biochemical oxygen demand (BOD) or chemical oxygen demand (COD). For MHFs, the concentration of suspended solids in the water depends upon scrubber efficiency and incinerator type. For FB, higher concentrations of suspended solids in the water may be found. Scrubber water from both MHF and FB incineration units will be high in dissolved CO_2, low in pH, and contain trace elements.

The scrubber water is usually treated separately by flocculation and sedimentation to reduce its solids content. Residue produced during scrubber water treatment may be dewatered and disposed of with the incinerator ash. Treated scrubber water effluent after solids removal is almost universally recycled back through the wastewater treatment plant influent. However, problems do occur at the POTW that are due to rapid build-up of total dissolved solids. Thus, scrubber water effluent is assumed to be treated to the point where any remaining contaminants pose no significant human health risk.

4. METHODOLOGY FOR AIR EMISSIONS PATHWAY

4.1. OVERVIEW OF METHOD

Selection of critical pathways involves identifying the waste streams that have the potential for creating an adverse impact on humans. The potential for an adverse impact from air emissions, ash residue and scrubber water depends on the assumptions made about how these waste streams are handled and how they behave in the environment. General practice involves treating and recycling the scrubber water back to the wastewater treatment plant or incineration process or to a landfill. A groundwater methodology has been developed for landfilling of sludge that may be used for leaching of scrubber water (U.S. EPA, 1986).

The ash residue from an incinerator may be either bottom ash, fly ash or both, depending upon the type of incinerator. Where both bottom ash and fly ash are obtained, they are usually mixed to form a composite residue. If EPA-EP toxicity testing shows that a particular ash is hazardous, disposal should be in an appropriately permitted landfill.

The greatest concern associated with air emissions from incinerators is the potential public health risk associated with the inhalation of airborne gases and particulates. Certain of the emitted contaminants are suspected human carcinogens while others can exert other acute or chronic effects. Thus, incinerator air emissions are selected as the critical pathway in evaluating human health risk from the sludge incineration process.

The methodology requires that the human health and environmental impacts be defined by the following:

1. Identify the human health and environmental impacts and exposures considered acceptable (Chapter 5).
2. Define the human population exposed to the ground level ambient concentrations for representative facilities (Chapter 5).

3. Define, for the air exposure route, the maximum allowable daily and annual ground level concentrations of the pollutants of concern that will satisfy the health and exposure criteria in Step 1 (Chapters 4 and 5).

4. Define the stack modeling characteristics, such as stack height, exit diameter, gas flow, gas temperature, and meteorology for selected model plants (Chapter 4).

5. Select the appropriate air dispersion model(s) for the models/plants and calculate the emission rates associated with the acceptable ambient concentrations (Chapter 4).

6. Calculate allowable sludge concentrations and mass loadings for the pollutants of concern (Chapter 6).

The major assumptions for these steps are given in Table 4-1.

4.2. FATE AND TRANSPORT

4.2.1. POTW Incinerator Data Base. The U.S. EPA's Office of Air Quality Planning and Standards in early 1985 performed a telephone survey of 127 incinerator sites in the United States. The survey included 80% or more of all operational POTW incinerators in the country. The survey contains locations and coordinates of the 127 facilities, as well as data on the capacity of the incinerators, the types of incinerators, building dimensions, the stack parameters and the type of gas scrubbing equipment.

An analysis of the data base revealed the following information:

- The 127 sites have a total of 227 incinerators categorized as follows:
  - -- 192 multiple hearths
  - -- 23 fluidized beds
  - -- 5 electric (infrared) furnaces
  - -- 7 coincineration with solid waste facilities
- The total capacity of all of the incinerators is 8175 dry metric tons of sludge per day. The distribution of capacity for the 127 sites is shown in Figure 4-1. The average capacity is 35 dry metric tons per day.

TABLE 4-1

Major Assumptions for the Sludge Incineration Methodology

Assumptions	Reason(s)
Modeling was performed using a unit emission rate of 1 g/sec for each plant incinerator stack.	Actual concentrations can be obtained at each receptor by scaling the 1 g/sec concentrations by the actual pollutant-specific emission rate after the modeling has been completed. This was used because of lack of actual emissions data for pollutants of concern.
The MEI resides in the area of the maximum ground level concentration and is exposed 24 hours/day.	Consistent with other Agency policies.
The incinerator is assumed to be operational for the life of the individual (70 years) and on-stream 100% of the time.	Wastewater treatment plants are expected to be operated indefinitely into the future.
Body weight of adult MEI is 70 kg for cancer. Body weight for systemic toxicants will vary depending upon the age group of the MEI.	Consistent with other Agency policies.
-5 Risk level of exposure to carcinogens is set at 10^{-6} (an upper-bound excess cancer risk of one case in one million exposed individuals over the background cancer rate).	Consistent with ~~other~~ Agency ~~studies~~ ~~and~~ policies.
Volume of air respirated on a daily basis is 20 m^3/day for a 70 kg adult.	Consistent with other Agency studies and policies.
Human exposure is assumed to be 100% of the annual average.	Consistent with EPA assumptions for exposures calculated in other studies.
Only source of exposure is inhalation of ambient air impacted by sludge incinerator emissions.	Exposure from incinerator ash will be regulated under RCRA (Subtitle D); exposure from scrubber water will be regulated under the CWA using NPDES permits.*

TABLE 4-1 (cont.)

Assumptions	Reason(s)
Indoor and outdoor air concentrations are the same.	Model cannot adequately take into account the indoor/outdoor distribution of air concentrations.

*Terrestrial deposition model may need to be developed to assess human exposure.

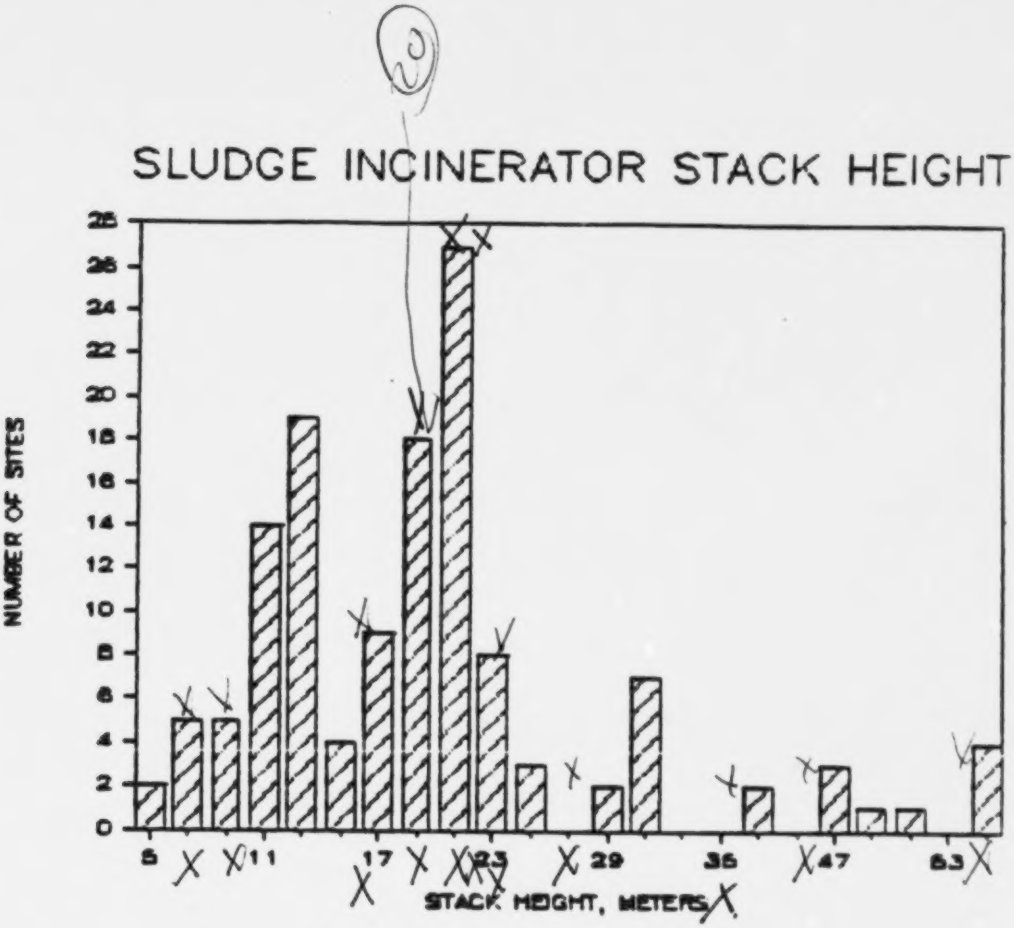


FIGURE 4-1

Distribution of Stack Heights for Sludge Incinerators

- The distribution of stack heights is presented in Figure 4-2.
- The distribution of stack exit gas velocities is shown in Figure 4-3.
- The average operating week is 5 days.
- The distribution of air pollution control systems by incinerator type is shown in Table 4-2.

4.2.2. **Model Plant Selection Criteria.** Based on the EPA survey, Ten ~~eight~~ facilities were selected to represent the different conditions for sludge incinerators in the United States. The selection of the model study plants was made using the following factors:

- Capacity - Total incinerator capacity in dry tons per day;
- Stack height - Stack height above ground level in meters;
- Stack exit velocity - Stack exit velocity in meters per second;
- Population - Population density around the facility, either rural or urban;
- Terrain - Locations where terrain is known to be a potential factor in causing increased human exposure;
- Meteorology - Locations where meteorological factors may cause increased human exposures, i.e., frequent atmospheric inversions.

The following ranges were selected for each of the above factors:

Capacity: Based on the distribution of incineration capacity in Figure 4-1, the following three ranges were selected:

- Maximum single site capacity
- 90-100 dry tons per day
- Less than 10 dry tons per day

Stack Height: Based on the distribution of stack heights in Figure 4-2, the following ranges were identified:

- 5-7 meters
- 18-20 meters
- 44-46 meters

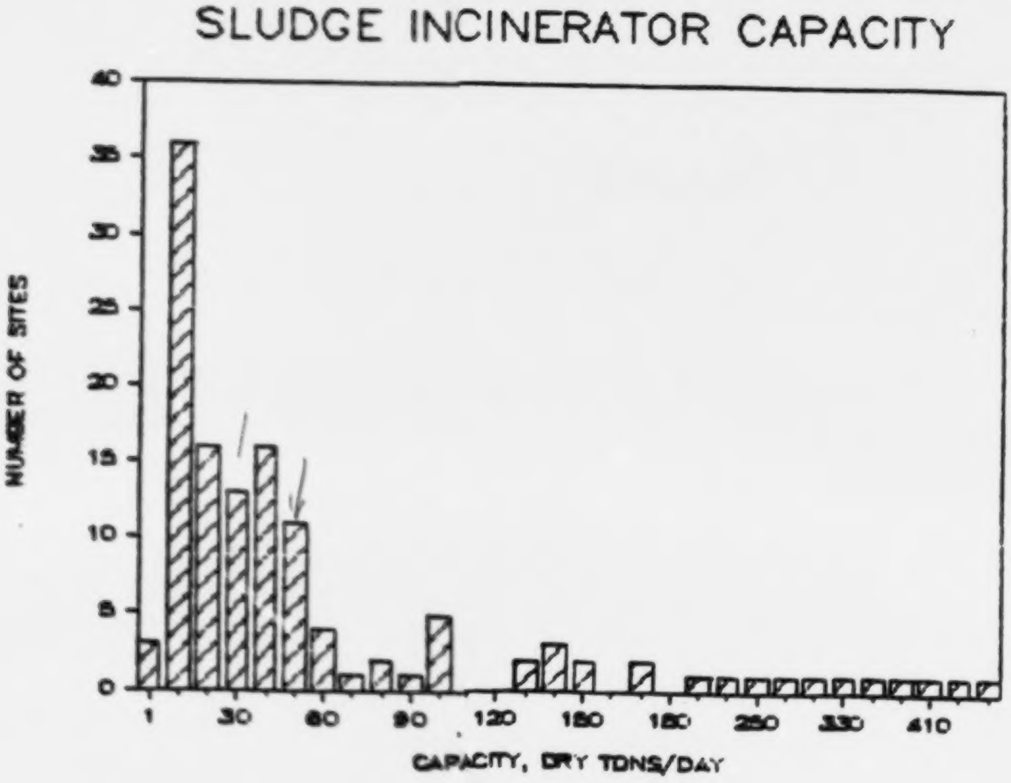


FIGURE 4-2

Distribution of Capacity for 127 Sludge Incinerator Sites

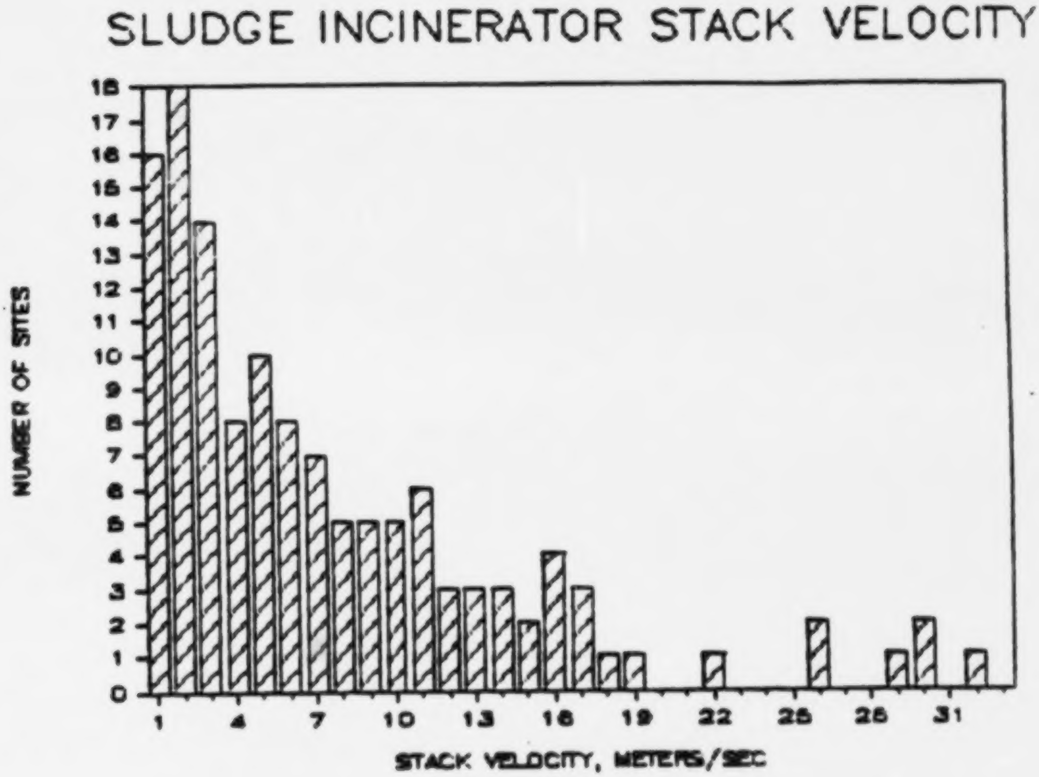


FIGURE 4-3

Distribution of Stack Exit Gas Velocities for Sludge Incinerators

TABLE 4-2

Air Pollution Control Systems by Furnace Type

	Multiple Hearth	Fluidized Bed	Electric Furnace	Coincineration
Wet scrubbers (unspecified)	64	6		
Venturi/impingers	53	3	2	
Venturi/packed tower		2		
Impingers	36	3		
Wet cyclone	17	1		
Venturi	25	6	3	3
Wet cyclone/impinger	1			
Spray chamber	1	2		
Unknown	3			
ESP				4

Check nos!

Stack exit velocity: Based on the distribution of exit gas velocities in Figure 4-3, the following ranges were selected:

- 16 meters per second
- 10 meters per second
- 3 meters per second

Population: Population near a wastewater treatment plant should present a fairly high degree of capacity of the treatment plant and the incinerator capacity. Therefore, the selection of the model plants based on total incineration capacity should also reflect the regional population.

Terrain: At least 3 of the 10 facilities selected should have terrain in close proximity to the incinerator stack, which is above the elevation at the stack.

Meteorology: At least two of the facilities selected should be in locations where inversions or other unfavorable meteorological conditions exist.

4.2.3. Facilities Selected. The 10 representative facilities selected are shown for operating conditions and for design conditions in Table 4-3. Each facility is modeled for two different conditions. The operating conditions represent current practice at that facility. The design conditions represent potential future practice (maximum capacity). Each of these 10 facilities was picked for one or more of the following reasons:

Facility 1: This facility has a moderate capacity and a large number of residences located above the stack level.

Facility 2: This facility is a small capacity electric furnace facility with a short stack.

Facility 3: This facility was picked because it has a small capacity fluidized bed incinerator, and although located in a rural setting, is sited in a valley on the Mississippi River.

Facility 4: This facility was selected because of its median capacity and tall stacks.

Facility 5: This facility is the largest incineration facility in the United States with a capacity of 1080 dry metric tons per day.

TABLE 4-3

Facility Coordinates, Stack Parameters and Building Dimensions of the Sewage Sludge Incinerator Plants
(actual operating and design conditions)

Facility	Latitude	Longitude	UTM (km)			Land Use^a	No. of Flues	Stack Parameters					Building Dimensions			
	(dg:mn:sc)		Zone	North	East			Height (m)	Diameter (m)	Temp. (°K)	Velocity (m/s)	Flow (acms)^b	Height (m)	Length (m)	Width (m)	Effective Width (m)
1	38:50:43	77:03:20	18	4301.4	321.6	U	1 (2)	35.4	0.91	338	14.0	9.021	18.3	26.5	33.9	25.2
2	34:15:59	83:52:01	17	3795.2	236.0	R	2	7.6	0.51	311	7.00 (7.70)	1.46 (1.61)	5.5	31.7	23.5	27.3
3	42:20:02	90:39:34	15	4704.3	692.5	R	1 (2)	16.2	0.61	308	11.83	3.45	10.7	54.9	54.9	84.9
4	39:14:02	76:34:05	18	4343.7	364.7	U	2 (3)	21.8	0.91	308	6.15 (7.70)	4.03 (5.11)	16.3	54.9	14.1	27.8
5	(existing)															
Complex 1	42:17:07	83:07:54	17	4683.3	324.2	U	5 (6)	22.0	1.32	310	14.3	19.6	29	82.0	64.0	72.4
Complex 2	42:17:07	83:07:54	17	4683.3	324.2	U	6 (8)	44.0	1.32	307	15.7	21.5	29	82.0	64.0	72.4
5	(proposed)															
Complex 1	42:17:07	83:07:54	17	4683.3	324.2	U	1	76.2	5.11	315	4.78 (5.70)	98 (129)	29	82.0	64.0	72.4
Complex 2	42:17:07	83:07:54	17	4683.3	324.2	U	2	76.2	4.67	315	3.77 (5.02)	64.5 (86.0)	29	82.0	64.0	72.4
6	39:06:31	84:32:38	16	4331.5	712.4	U	3 (4)	23.3	0.8	325	20.0	10.12	18.3	73.2	55.5	63.7
7	41:25:37	81:39:10	17	4586.2	445.4	U	3 (4)	27.4	0.91	318 (308)	12.10 (18.98)	7.95 (12.46)	25.0	48.0	48.0	48.0
8	44:31:59	87:59:54	16	4931.3	420.7	U	1 (2)	55.1	1.52	330 (329)	6.30 (11.3)	11.50 (20.5)	18.3	36.6	36.6	36.6
9	40:50:07	73:42:10	18	4521.1	609.4	U	1	9.2	0.46	308	10.10	1.66	6.8	29.3	28.5	28.9
10	35:57:13	77:47:07	18	3982.2	248.8	R	1	18.3	0.58	308	9.31	2.46	15.3	15.1	8.5	11.3

^{a}Urban or rural

^{b}Actual cubic meters/second

( ) - Design conditions

Facility 6: This facility is located in an area with a large number of residences on a hill adjacent to the incinerator stacks. It is also a moderately large capacity facility.

Facility 7: This facility was picked because it has a large capacity and median stack heights.

Facility 8: This facility has a capacity close to the median and has a very tall stack in a rural area.

Facility 9: This facility has only one unit, FB incinerator with a very low capacity.

Facility 10: This facility has only one unit, MHF incinerator, and is located in a rural area.

The selection of these 10 facilities and the subsequent air dispersion modeling provide a range of conditions that result in an evaluation of the impact of the major variables of capacity, stack height, terrain and meteorology on allowable emissions.

4.2.4. Modeling Long-Term Average Concentration Patterns. Since the actual emission rate of each chemical was unknown, modeling was performed using a unit emission rate (1 g/sec) for each plant incinerator stack to establish long-term average concentration patterns. This was done so that actual concentrations of each chemical species can be obtained by scaling the concentration pattern by the actual species-specific emission rate after the modeling has been completed. This has the same effect as rerunning the model using the actual emission rate for each emitted pollutant.

The unit incinerator emissions were modeled using EPA-approved computer codes and methods (U.S. EPA, 1984c). The models used in the study were selected according to the applicability to urban or rural areas, simple or complex terrain and available model options (such as building aerodynamic downwash). The models selected and the rationale for selection is provided below:

> Industrial Source Complex Long-Term (ISCLT) was utilized to assess urban or rural concentrations when including the effects of building aerodynamic downwash.
>
> LONGZ was used to model for surface concentrations in urban complex terrain.
>
> COMPLEX I was used to compute surface concentrations in rural complex terrain.

4.2.4.1. MODEL SELECTION -- Most of the sewage sludge incinerators have short stacks that are not much higher than the buildings in which they are located. As a result, aerodynamic building downwash was the primary concern for the sludge incinerator assessment. Therefore, the model that was the primary tool of the assessment was the ISCLT since it is the only EPA-accepted atmospheric dispersion model that considers the effects of building aerodynamic downwash in computing concentrations. The limitation of the ISCLT model is that it is only intended to compute concentrations in simple terrain (terrain less than or equal to stack height). Consequently, in the case where receptors were located in complex terrain (terrain greater than stack height), a supplemental model was used.

ISCLT model options that were used in the assessment are specified in Table 4-4. A brief description of the ISCLT model is provided below. For more information on the ISCLT model, refer to the ISCLT model user's guide (U.S. EPA, 1979).

The ISCLT model:

> Uses the climatological form of the steady-state Gaussian plume equation for a continuous source;
>
> Uses the generalized Briggs (1969, 1971, 1972) plume rise equations (including momentum terms) to compute plume rise;

TABLE 4-4

Options Used in the ISCLT Modeling

Model	Description of the Option
ISCLT	Wind direction and speed, and Pasquill-Gifford (P-G) stability data were input in the form of the STAR data.
	Annual mixing heights for each site were obtained from the Holzworth (1972) mixing height study and were input by stability class according to ISCLT guidance.
	Annual ambient air temperatures were obtained from local climatological data summaries and were input by stability class according to ISCLT guidance.
	Wind profile exponents used were the following for P-G stability classes A through F: rural applications -- 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 urban applications -- 0.15, 0.15, 0.20, 0.25, 0.30, 0.30
	The mid-point of the first wind speed class for the STAR input data was specified to be 1.5 meters per second instead of the ISCLT default 0.75 meters/second.
	Vertical potential temperature gradients and entrainment coefficients used were ISCLT default values.
	The rural mode was used for all rural sites and the urban mode 3 was used for all urban sites. Rural or urban land uses were decided according to the EPA guidance document (U.S. EPA, 1984c).
	Plume rise was specified to be distance-dependent.
	Wind system measurement height was set to 10 meters.
	Terrain effects were used.
	Polar coordinate receptors were used to describe worst-case downwind concentrations.
	Only stack sources were modeled and unit emission rates (i.e., 1 g/second) remained constant in time.
	Aerodynamic building downwash analysis was done.

TABLE 4-4 (cont.)

Model	Description of the Option
	Program control parameters, receptors and source input data were output. Annual concentrations were calculated and output.

Uses the Pasquill-Gifford (P-G) curves (Turner, 1970) to compute vertical dispersion;

Uses sector-averaging instead of explicit lateral dispersion. Setor-averaging is the assumption that, over the long averaging time involved, the plume will be found at many azimuths. That is, during many hours of "east" winds, the plume at times may be blown down the center, either edge, or elsewhere within a 22.5° segment of arc to the west;

Uses the formulas of Huber and Snyder (1976) and Huber (1977) to compute building downwash;

Uses wind profile exponents to compute wind speed variation with height according to stability for either rural or urban applications;

Uses meteorological data input as follows: statistical summaries that categorize winds into 16 compass-point directions, six wind speed classes, and six P-G stabilities;

Allows receptors to be input as polar or cartesian coordinates; and

Allows mixing height and temperature to be specified according to stability.

When the dispersion of incinerator emissions in complex terrain was assessed for an urban area, LONGZ was used to supplement the ISCLT modeling results. The LONGZ model options utilized in the assessment are indicated in Table 4-5. A brief description of LONGZ is provided below. For more information on the LONGZ model, refer to the LONGZ user's guide (U.S. EPA, 1982).

The LONGZ model differs from the ISCLT model as follows:

LONGZ: Uses different plume rise equations (Bjorklund and Bowers, 1982);

Uses vertical turbulence intensities to compute vertical plume dimensions;

Uses "Cramer dispersion coefficients" rather than the P-G dispersion curves used in ISCLT and COMPLEX I; and

Does not treat aerodynamic building downwash as does ISCLT.

TABLE 4-5

Options Used in the LONGZ Modeling

Model	Option Description
LONGZ	Wind direction and speed, and P-G stability data were input in the form of STAR data. Annual average morning and afternoon mixing height were obtained from the Holzworth (1972) mixing height study and input. Annual concentrations were calculated and output. Terrain were utilized. The mid-point of the first wind speed class for the STAR input data was specified to be 1.5 meters per second instead of the LONGZ default 0.75 meters/second. Wind speed power law was based on an emission elevation above the meteorological data measurement elevation [i.e., ISW(9)=0]. Polar coordinates were used. The model was run in the urban mode. Entrainment coefficients, dispersion parameters and wind profile exponents were selected to be default values for LONGZ.

When incinerator emissions impacts were assessed in rural complex terrain, COMPLEX I was used to supplement ISCLT modeling results. COMPLEX I model options used in the assessment are shown in Table 4-6. A brief description of COMPLEX I is given below. COMPLEX I is largely based on the MPTER model. Since there is no user's guide for COMPLEX I, for further information on the COMPLEX I model refer to the MPTER model user's guide (U.S. EPA, 1980). The differences from MPTER are given in comment statements in the first few pages of the COMPLEX I source code (U.S. EPA, 1983a).

The COMPLEX I model:

> Is a rural complex terrain model that uses the steady-state Gaussian plume equation for each hour of a meteorological record in sequence;
>
> Does not use statistical wind summaries as does ISCLT and LONGZ;
>
> Like ISCLT, uses Briggs (1969, 1971, 1972) plume rise, P-G dispersion curves, and sector-averaging instead of explicit horizontal dispersion;
>
> Computes the change in wind speed with height according to stability using wind profile exponents; and
>
> Uses meteorological data input in the form of hourly observations of wind speed, wind direction, temperature, stability and mixing height.

The COMPLEX I model is not a climatological model (although it computes annual concentrations), nor does COMPLEX I use statistical wind summaries as input. VALLEY does not use statistical wind summaries. However, VALLEY lacks two options that are desired in this assessment that are incorporated in COMPLEX I -- the computation of the change of wind speed with height using wind profile exponents, and the adjustments made to the plume height according to terrain and atmospheric stability. Thus, COMPLEX I instead of VALLEY, was selected for use in modeling in rual complex terrain.

TABLE 4-6

Options Used in the COMPLEX I Modeling

Model	Description of the Option
COMPLEX I	Wind direction and speed, and P-G stability data were selected from STAR data and converted into sequential hourly observations that were usable by COMPLEX I. Annual morning and afternoon mixing heights for each site were obtained from the Holzworth (1972) mixing height study. Mixing height was computed to vary with stability according to ISCLT and LONGZ guidance and was input with the sequential hourly meteorological data. Ambient air temperature was specified to vary according to stability class using ISCLT and LONGZ guidance and was input with the sequential hourly meteorological data. Wind profile exponents utilized were the following for P-G stability classes A through F: 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 Plume rise was specified to be distance-dependent. Wind system measurement height was set to 10 meters. Minimum plume height-to-complex terrain was set to 10 meters. Terrain effects were utilized and the terrain adjustment factors for P-G stability classes A through F are as follows: 0.5, 0.5, 0.5, 0.5, 0.0, 0.0 Polar coordinate configured receptors were converted to cartesian coordinates to describe worst-case downwind concentrations. Only stack sources were modeled and unit emission rates (i.e., 1 g/sec)remained constant in time. Program control parameters, receptors and source input data were output. Annual concentrations were calculated and output.

In order to use COMPLEX I in a manner similar to ISCLT and LONGZ, modifications to the input data and processing of the receptor concentration results were required. These modifications are discussed below.

COMPLEX I can compute concentrations at a limited number of receptors. Modeling the incinerator emissions required more receptors than could be modeled in a single COMPLEX I run. Thus, multiple model runs were performed and the receptor concentration results merged.

The model can only use sequential hourly meteorological data as input. Consequently, to use the same data that were input into ISCLT, a substitute statistical wind summary was needed.

Modeling the emulated statistical wind summary produced receptor concentrations for each hour of meteorological data. These hourly receptor concentrations were then multiplied by the appropriate statistical wind summary frequency factor, and each respective receptor concentration was summed over all stabilities to obtain the annual mean concentration for each receptor. The concept underlying this approach is explained in Section 4.2.4.6.

4.2.4.2. MERGING MODELING RESULTS -- ISCLT was used to model all receptor concentrations because it incorporates the effects of building aerodynamic downwash. In order to apply ISCLT at complex terrain receptors, the complex terrain receptor elevations were set equal to stack height. Complex terrain receptors were also modeled using actual elevations with the LONGZ model for urban facilities and the COMPLEX I model for rural facilities (see Table 4-8 for rural/urban classification of facilities). The ISCLT and either LONGZ or COMPLEX I results were compared to find the higher concentration for each complex terrain receptor. The higher concentration was then selected and merged with the ISCLT simple terrain receptor results to obtain the complete input data file for the Human Exposure Model (HEM).

R /

4.2.4.3. BUILDING AERODYNAMIC DOWNWASH -- The ISCLT model is recommended for computation of building downwash (U.S. EPA, 1984c). Receptors and building dimension input were specified according to U.S. EPA associated methods. According to U.S. EPA guidance (U.S. EPA, 1983b), addressing downwash requires receptors to be located from 100 m to 2 km downwind of the source at 100 m intervals. The ISCLT model requires the input of the width of the building adjacent to the stack. If the building is not square, the "effective width" of a square building of equal horizontal area is input.

The "effective width" for each facility configuration is shown in Table 4-3.

4.2.4.4. **RECEPTOR GRID SPECIFICATION** -- Receptors are used beginning at the distance of 100 meters from the modeled source to 2000 meters from the source at 100 meter increments. The receptors were configured in polar coordinates with 16 compass-point radials (e.g., north, north-northeast). When modeling multiple sources, the grid was centered between the sewage sludge incinerator stacks to allow symmetric representation of concentration contours about the facility. Downwind rings beyond 2000 meters were specified at 5000, 10,000, 20,000 and 50,000 meters.

Additional receptor rings were included based on the results of incinerator plume rise screening modeling. Screening modeling of the incinerators plume rise was performed using the EPA-approved model PTPLU. This model computes the worst-case surface concentrations at downwind distances according to stability and wind speed. The PTPLU-computed downwind distance of the highest concentration for each stability class was included in the receptor grid. If the indicated rings were at a distance <2000 meters (where receptors selected for the aerodynamic building downwash were already specified at 100 meter intervals), they were not used. Table 4-7 shows the ring distances utilized in the study according to the facility modeled.

The PTPLU model output also describes the plume height of the worst-case downwind concentration according to wind speed and stability. This height can be used to select receptor elevations that will describe worst-case complex terrain surface concentrations that are due to plume impingement.

TABLE 4-7

Ring Distances According to Facility Modeled

Facility	Receptor Ring Distances (km)
1	0.104, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2., 2.17, 3.67, 3.99, 5.0, 10.0, 20.0, 50.0
2	0.105, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 5.0, 10.0, 20.0, 50.0
3	0.120, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 5.0, 10.0, 20.0, 50.0
4	0.125, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 5.0, 10.0, 20.0, 50.0
5	0.161, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1..2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 3.0, 3.318, 5.0, 6.186, 6.323, 10.0, 14.913, 15.0, 20.0, 50.0
6	0.115, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.198, 5.0, 10.0, 20.0, 50.0
7	0.122, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.87, 5.0, 8.96, 10.0, 20.0, 50.0
8	0.116, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 3.0, 3.949, 5.0, 7.979, 10.0, 20.0, 50.0
9	0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 5.0, 10.0, 20.0, 50.0
10	0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 5.0, 10.0, 20.0, 50.0

PTPLU model results of meteorological conditions conducive to plume impingement on complex terrain (i.e., P-G stability class "F" at 2.5 meters per second) were used to find the critical plume height. U.S. Geological Survey maps were used to select polar coordinate receptor elevations.

As was indicated in earlier sections, the COMPLEX I receptors needed special treatment because COMPLEX I is typically not used as a climatological model. The 16 compass-point radials normally input into ISCLT and LONGZ could not be used because the COMPLEX I model requires radials in 10 degree increments. Therefore, the 16-point radials and rings were processed to obtain cartesian coordinate receptors. The cartesian receptors were then used when modeling with COMPLEX I.

4.2.4.5. **LAND USE DESCRIPTION** -- Rural or urban dispersion coefficients and wind profile coefficients were selected according to U.S. EPA guidance (U.S. EPA 1984c). This was achieved by means of a land-use-type scheme (Auer, 1978) to assess land use within a 3 km radius of the facility. According to the scheme, if certain land-use types corresponding to urban descriptions account for >50% of the area within the 3 km radius, urban dispersion and wind profile coefficients should be used. Conversely, if rural land-use types account for >50% of the area within 3 km radius, rural dispersion and wind profile coefficients should be used. The results of this assessment are indicated in Table 4-3.

4.2.4.6. **METEOROLOGICAL DATA SELECTION** -- The meteorological data used by the ISCLT and LONGZ models were input in the form of joint frequency distributions broken down by wind speed, wind direction and Pasquill-Gifford (P-G) stability. These data, sometimes referred to as "statistical wind summaries," are also known as Stability ARray (STAR) data and are generally available for major commercial airports. Table 4-8 describes the sludge

TABLE 4-8

Meteorological Input Data for ISCLT and LONGZ MOdels

Facility	Period of Record	Time Between Observations (hours)	Summary Type
1	1966-1970	3	annual
2	1959-1963	1	annual
3	1960-1964	1	annual
4	1969-1973	3	annual
5	1969-1973	3	annual
6	1958-1962	1	annual
7	1969-1973	3	annual
8	1964-1973	3	annual
9	1965-1970	3	annual
10	1966-1970	1	annual

incineration sites and the nearest available meteorological stations for which STAR data were available. The data dets selected represent the best available data found in the area of each sludge incineration facility.

Stability class data for each STAR distribution were evaluated for neutral stability day-night splits and unit total frequency. Day-night neutral distributions were combined to obtain an overall neutral stability class. All STAR data base frequency of occurrence totals summed to unity.

The ISCLT and LONGZ models utilize annual mixing heights and temperatures according to stability. Annual mixing height and ambient temperature data were taken from climatological literature (Holzworth, 1972; NOAA, 1978) and were specified to vary by stability according to ISCLT and LONGZ guidelines. Table 4-9 shows the mixing heights and temperatures according to stability that was used as input in the modeling assessment for each facility.

The special treatment required for the COMPLEX I meteorological wind data consisted of developing an appropriate wind summary for the site by using hourly meteorological data. The statistical wind summary was developed by specifying each hour of meteorological data to correspond with each wind direction, wind speed and stability combination of the wind summary. The basis for this approach is that, in effect, the resultant concentration at a receptor for one modeled hour of a wind speed, wind direction and stability is the same as the annual average concentration at the same receptor for 1 year (8760 consecutive hours) of the same wind speed, wind direction and stability.

Each receptor was modeled for all combinations of stability, wind speed and wind direction found in the statistical wind summary. These receptor

TABLE 4-9

Mixing Height and Ambient Temperature Data According to Stability and Facility

Facility	Data	Pasquill-Gifford Stability					
		A	B	C	D	E	F
1	temperature	292	292	292	287	282	282
	mixing height	2255	1503	1503	971	439	439
2	temperature	288	288	288	280	275	275
	mixing height	1760	1173	1173	794	415	415
3	temperature	288	288	288	283	278	278
	mixing height	1938	1292	1292	849	406	406
4	temperature	287	287	287	281	276	276
	mixing height	1700	1113	1113	766	419*	419*
5	temperature	294	294	294	289	284	284
	mixing height	2243	1495	1495	910	324	324
6	temperature	285	285	285	280	275	275
	mixing height	1760	1173	1173	794	415	415
7	temperature	291	291	291	286	280	280
	mixing height	1985	1323	1323	866	408	408
8	temperature	291	291	291	286	280	280
	mixing height	2255	1503	1503	971	439	439
9	temperature	289	289	289	286	282	282
	mixing height	1352	901	901	888	875	875
10	temperature	294	294	294	288	282	282
	mixing height	1950	1300	1300	950	600	600

*Temperature is in degrees Kelvin; mixing height is in meters.

concentrations were output for each hour of meteorological data. The annual average concentrations were then obtained by processing these hourly concentrations with the appropriate wind summary frequency factor and summing each receptor concentration over all stabilities.

5. EXPOSURE AND ASSESSMENT OF HEALTH EFFECTS

Two approaches for exposure health assessment may be performed by this methodology: an aggregate risk and the most exposed individual (MEI). The human exposure model (HEM) assesses aggregate risk as described in Section 5.1. The MEI methodology is described in Section 5.2.

5.1. HUMAN EXPOSURE MODEL (HEM)

The U.S. EPA's Office of Air Quality Planning and Standards' Pollutant Assessment Branch has developed a human exposure model. The impact parameters (exposure, hazard and risk) are the basis of the HEM computations of the individual and community health effects resulting from the emissions of chemical species. These concepts are defined as follows:

Population -- The number of persons in contact with the concentration.

Exposure -- The population multiplied by the concentration.

Carcinogenic Potency -- This parameter is quantified by the unit risk factor, the probability of developing cancer due to continuous exposure to 1 $\mu g/m^3$ of the species over a 70-year lifetime.

Hazard -- Concentration multiplied by the unit risk factor.

Risk -- Exposure multiplied by the unit risk factor.

The human exposure model uses a finely detailed national census data base to compute the impact parameters of exposure and dose (Anderson et al., 1981; Anderson and Lundberg, 1983). The resulting risk patterns are dependent not only on concentration, but on population patterns.

5.1.1. Exposure. The degree of contaminant exposure to individuals residing in an area where emissions from a municipal sludge incinerator exist depends upon the following:

- the duration of exposure;
- the volume of air inhaled;
- the particle size distribution for incinerator emissions;
- the annual average contaminant concentrations; and
- the number of people exposed.

5.1.1.1. **EXPOSED POPULATION** -- The population that is assumed for the exposure estimate is from the 1980 census population data. The population is located within a 50 km radius for each case-study incinerator. This approach calculates the annual ground level concentration from the stack for the area around the incinerator and then superimposes the location and numbers of people on a concentration grid. The exposures are calculated for each section of the grid and then are summed to give an aggregate risk value for the total population. The assumption of a 70-year exposure is used to calculate the lifetime aggregate cancer risk.

The exposure estimate includes consideration of the amount of time that the individual spends in a location exposed to the incinerator emissions. Also, the duration of exposure is affected by the percentage of time on an annual basis that the incinerator is operational and the expected operating life of the system.

5.1.2. Inhalation Volume. This refers to the volume of air inhaled on a daily basis. A volume of 20 m^3/day is assumed, which is consistent with other Agency analysis and the U.S. EPA's Carcinogen Assessment Group calculations.

5.1.3. **Particle Size Distribution.** This refers to the distribution of sizes of the particulate emitted from the incinerator. For this analysis, it is assumed that 100% of the inhaled particulate enters and is retained in the upper and lower respiratory tract. Any clearance of particulates from the upper respiratory tract results in particulate ingestion and absorption.

5.1.4. **Contaminant Concentration.** Ambient concentrations are predicted in terms of an annual average in micrograms per cubic meter ($\mu g/m^3$). The human exposure is assumed to be 100% of the annual average, which is consistent with the U.S. EPA assumptions for exposures calculated in other Agency studies.

5.1.5. **Model Description.** The model consists of two major computational algorithms and major input data files. The two algorithms used are 1) a plume dispersion computation algorithm and 2) exposure/risk algorithm. The HEM does not make use of the plume computation module since the annual concentration patterns will be computed using more sophisticated U.S. EPA approved atmospheric dispersion models (U.S. EPA, 1984c) described in Chapter 4. The exposure/risk algorithms involve joint processing of the computed concentration patterns and human population data files. Population data resolved at the level of census enumeration districts are used with specifically located facility concentration patterns.

5.1.6. **HEM Estimation Scheme.** A two-level scheme was adopted to pair up concentrations and populations before computing exposures and risks. The two-level approach is appropriate because the concentrations are defined on a radius-azimuth (polar) grid pattern with nonuniform spacing, because the fine/coarse relationship varies with radius. At small radii, the grid cells are much smaller than BG/EDs; at large radii the grid cells are much larger than BG/EDs. To form the product of the population times concentration, both factors at the same set of points are required. Techniques to accomplish this are most appropriately applied by interpolating values of the factor defined on the coarse network at the locations of the finer grid, thus maximizing the resolution and minimizing the uncertainties of interpolation.

For BG/ED centroids located between 0.1 and 2.8 kilometers from the source, populations will be apportioned among neighboring concentration grid points. Associated with each of these grid points, at which the concentration is known, is a smaller polar sector bounded by two concentric arcs and two radial lines. The boundary concentric arcs were the downwind receptor rings (located at 0.1, 0.2, etc., kilometers from the source), and the boundary radial lines will be drawn in the middle of two wind directions. Each of these concentration grid points will be assigned to the nearest BG/ED centroid identified in the population data set. The population at each centroid will then be apportioned among all concentration grid points assigned to that centroid. The exact land area within each polar cell will be considered in the apportionment, and the population density will be assumed to be the same for all grid cells assigned to a single centroid. Both concentration and population counts will be available for each polar grid point.

Log-linear interpolation will be used to estimate the concentration at each BG/ED population centroid located between 2.8 and 50 kilometers from the source. For each BG/ED centroid, four reference points will be located as the four corners of the polar sector in which the centroid is located. These four reference points would surround the centroid as depicted in Figure 5-1. The linear relationship that is known to exist between the logarithm of concentrations and the logarithm of distances for receptors >2

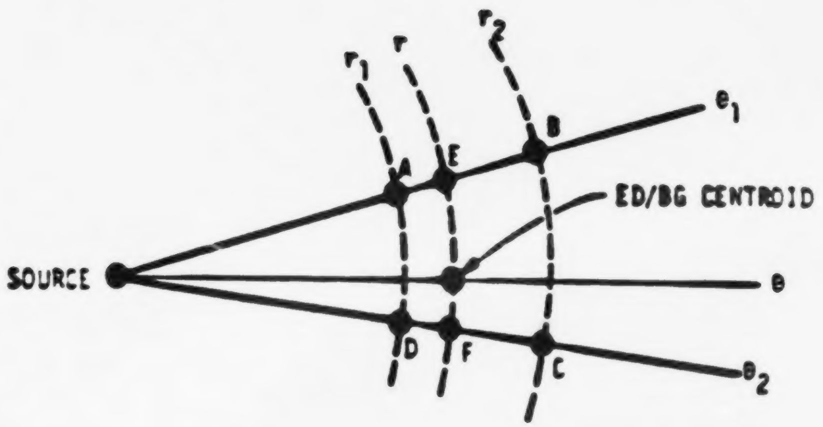

r_1
r
r_2
θ_1
A
E
B
ED/BG CENTROID
SOURCE
θ
D
F
C
θ_2

FIGURE 5-1

Reference Points for an Enumeration District/Block Group (ED/BG) Centroid kilometers away from the source would be used to estimate the concentrations at points E and F (see Figure 5-1). These estimates, together with the polar angles, will then be used to interpolate the concentration at the centroid.

5.2. MOST EXPOSED INDIVIDUAL METHODOLOGY (MEIM)

The most exposed individual (MEI) is assumed to reside in the area of the maximum annual ground level concentration and is exposed 24 hours a day. The incinerator(s) will be assumed to be operational for the life of the individual (70 years) and to be operating 100% of the time. The 70-year exposure is a valid estimate since sludge incinerators are expected to be operational indefinitely. The maximum concentration the MEI will be permitted to be exposed to for any particular contaminant is determined using the MEIM, which determines a ~~reference air concentration (RAC)~~ risk specific dose (RSD).

?

5.2.1. ~~Reference Air Concentration~~ Risk Specific Dose Derivation. ~~A reference air concentration~~ RSD ~~(RAC~~ RSD, in mg/m^3) is defined as an ambient air concentration used to evaluate the potential for adverse effects on human health as a result of sludge incineration. That is, for a given incinerator site, and given the practice definitions and assumptions stated previously in this methodology, the criterion is that sludge contaminant concentration which is calculated to result in air concentrations ~~below~~ at or below the ~~RAC~~ RSD at a compliance point downwind from the site. Exceedance of the ~~RAC~~ RSD would be a basis for concern that adverse health effects may occur in a human population in the site vicinity.

~~RAC~~ RSD is determined based upon contaminant toxicity and air inhalation rate, from the following generalized equation:

$$\text{Reference Air Concentration: } \cancel{\text{RAC}}\ \text{RSD}\ (\text{mg/m}^3) = I_p/I_a \qquad (5\text{-}1)$$

where I_p is the acceptable pollutant intake rate (in mg/day) based on the potential for health effects and I_a is the air inhalation rate (in m^3/day). This simplified equation assumes that the inhaled contaminant is

$$RSD = \frac{Risk \times 20}{Q_1^* \times 70}$$

absorbed into the body, through the lungs, at the same rate in humans as in the experimental species tested, or between routes of exposure (e.g., oral and inhalation). Also, this equation assumes that there are no other exposures of the contaminant from other sources, natural or manmade. I_p will vary according to the pollutant evaluated and to whether the pollutant acts according to a threshold or nonthreshold mechanism of toxicity as shown below.

5.2.1.1. **THRESHOLD-ACTING TOXICANTS** -- Threshold effects are those for which an acceptable (i.e., subthreshold) level of toxicant exposure can be estimated. For these toxicants, RSD ~~RAC~~ is derived as follows:

Reference Air Concentration: $$\text{RAC (mg/m}^3\text{)} = \left(\left(\frac{\text{RfD} \times \text{BW}}{\text{RE}}\right) - \text{TBI}\right) \div I_a \qquad (5\text{-}2)$$

where: RfD = Reference dose for inhalation (mg/kg/day)

BW = Human body weight (kg)

TBI = Total background intake rate of pollutant from all other sources of exposure (mg/day)

I_a = Air inhalation rate (m^3/day)

RE = Relative effectiveness of inhalation exposure (unitless)

The definition and derivation of each of the parameters used to estimate RSD ~~RAC~~ for threshold-acting toxicants are further discussed below.

5.2.1.1.1. **Risk Reference Dose (RfD)** -- When toxicant exposure is by ingestion, the threshold assumption has traditionally been used to establish an "acceptable daily intake," or ADI. The Food and Agricultural Organization and the World Health Organization have defined ADI as "the daily intake of a chemical which, during an entire lifetime, appears to be without appreciable risk on the basis of all the known facts at the time. It is expressed in milligrams of the chemical per kilogram of body weight (mg/kg)"

(Lu, 1983). Procedures for estimating the ADI from various types of toxicological data are outlined by the U.S. EPA (1980) (45 FR 79353-79356). More recently the Agency has preferred the use of a new term, the "risk reference dose," or RfD, to avoid the connotation of acceptability, which is often controversial.

RfD is defined for the purposes of this document as that dose, in mg/kg/day, which is estimated to be without effects in sensitive individuals during a lifetime inhalation exposure. RfD is estimated from observations in humans whenever possible. When human data are lacking, observations in animals are used, employing uncertainty factors as specified by existing Agency methodology.

Values of RfD for noncarcinogenic toxicants have been derived by several groups within the Agency. An effort is currently underway to verify these values and to produce a master list of RfDs for use by the various Agency programs. Most of the noncarcinogenic chemicals that are currently candidates for sludge criteria for the incineration pathway are included on the Agency's RfD list, and thus no new effort will be required to establish RfDs for deriving sludge criteria. For any chemicals not so listed, RfD values should be derived according to established Agency procedures.

5.2.1.1.2. **Human Body Weight (BW) and Air Inhalation Rate (I_a)** -- An assumption of 20 m^3 inhalation/day by a 70 kg adult has been widely used in Agency risk assessments and will be used in this methodology when adults are identified as the MEI. Table 5-1 shows values of I_a for a typical man, woman, child and infant with a typical activity schedule, as defined by the International Commission on Radiological Protection (ICRP, 1975). Additional values have been derived for an adult with the same activity schedule, but using upper-limit rather than average assumptions

TABLE 5-1

Daily Respiratory Volumes for "Reference" Individuals (Normal Individuals at Typical Activity Levels) and for Adults with Higher-than-Normal Respiratory Volume or Higher-than-Normal Activity Levels

(Volumes in m^3)

	"Reference" Man[a]	"Reference" Woman[a]	Upper-Limit Adult	Active Adult	"Reference" Child[a] (10 years)	"Reference" Infant[a] (1 year)
8-hour working, light activity	9.6	9.1	12.0[b]	--	6.24	2.5 (10 hours)
8-hour working, moderate activity	--	--	--	14.4[c]	--	--
8-hour nonoccupational (light) activity	9.6	9.1	12.0[b]	--	6.24	-
7-hour nonoccupational (light) activity	--	-	--	8.4	--	--
1-hour heavy activity	--	--	--	2.5[c]	--	--
8-hour rest	3.6	2.9	7.0[d]	3.6	2.3	1.3 (14 hours)
Total daily respiratory volume	22.8	21.1	31.0	28.9	14.78	3.8
Body weight (kg)	70	58	65	65	33	10
Ratio of Volume to body weight[e]	0.33	0.36	0.47	0.44	0.45	0.38

[a] Source: ICRP, 1975

[b] Upper-limit values for "ordinary man or woman," for "light" activity category (Astrand and Rodahl, 1977)

[c] Averaged values for "ordinary man or woman," for "moderate" or "heavy" activity categories (Astrand and Rodahl, 1977)

[d] Upper 95th percentile for adults, age 20-39 years, at rest (Fruhman, 1964)

[e] The inhalation volume-to-body weight ratios have been derived from the referenced values for illustrative purposes only.

about respiration rates for each activity; and for an adult with normal respiration rates, but whose work is moderately active and who practices 1 hour of heavy activity (i.e., strenuous exercise) per day (Fruhman, 1964; Astrand and Rodahl, 1977). Representative body weights have been assigned to each of these individuals to calculate a respiratory volume-to-body weight ratio. [Note: These ratios have been derived for illustrative purposes only.] The resulting ratio values range from 0.33-0.47 m^3/kg/day, all of which exceed the ratio value of 0.29 m^3/kg/day estimated from the 70 kg adult inhaling 20 m^3/day, as used currently by the Agency. Therefore, the typically-assumed values for adults may underestimate actual exposure. In cases where children and infants are known to be at special risk it may be more appropriate to use values of BW and I_a for children or infants.

5.2.1.1.3. Total Background Intake Rate of Pollutant (TBI) -- It is important to recognize that sources of exposure other than from the sludge disposal practice may exist, and that the total exposure should be maintained below the RfD. Other sources of exposure include background levels (whether natural or anthropogenic) in drinking water, food or air. Other types of exposure, that are due to occupation or habits such as smoking, might also be included depending on data availability and regulatory policy. These exposures are summed to estimate TBI.

Data for estimating background exposure usually are derived from analytical surveys of surface, ground or tap water, from FDA market basket surveys, and from air monitoring surveys. These surveys may report means, medians, percentiles or ranges, as well as detection limits. Estimates of TBI may be based on values representing central tendency or on upper-bound exposure situations, depending on regulatory policy. Data chosen to estimate TBI should be consistent with the value of BW. Where background data are reported in terms of a concentration in air or water, ingestion or inhalation rates applicable to adults or children can be used to estimate the proper daily background intake value. Where data are reported as total daily dietary intake for adults and similar values for children are unavailable, conversion to an intake for children may be required. Such a conversion could be estimated on the basis of relative total food intake or relative total caloric intake between adults and children.

For example, in deriving the National Emission Standard for mercury, the average dietary contribution of 10 µg Hg/70 kg/day was subtracted from the assumed threshold of 30 µg/70 kg/day to give an allowable increment from inhalation exposure of 20 µg/70 kg/day. An assumed inhalation volume of 20 m^3/day for a 70 kg man was then applied to derive an allowable ambient air concentration of 1 µg Hg/m^3 (U.S. EPA, 1984d). For the purposes of this methodology, however, TBI should be an estimate of background exposure from all sources, including inhalation.

As stated previously, the TBI is the summed estimate of all possible background exposures, except exposures resulting from a sludge disposal practice. To be more exact, the TBI should be a summed total of all toxicologically effective intakes from all nonsludge exposures. To determine the effective TBI, Background Intake values (BI) for each exposure route must be divided by that routes particular relative effectiveness (RE) factor. Thus, the TBI can be mathematically derived, after all the background exposures have been determined, using the following equation:

$$TBI = \frac{BI_{(food)}}{RE_{(food)}} + \frac{BI_{(water)}}{RE_{(water)}} + \frac{BI_{(air)}}{RE_{(air)}} + \ldots + \frac{BI_{(n)}}{RE_{(n)}} \qquad (5\text{-}3)$$

where: TBI = Total background intake rate of pollutant from all other sources of exposure (mg/day)

BI = Background intake of pollutant from a given exposure route, indicated by subscript (mg/day)

RE = Relative effectiveness, with respect to inhalation exposure, of the exposure route indicated by subscript (unitless)

5.2.1.1.4. **Fraction of Inhaled Air from Contaminated Area** -- It is recognized that an individual exposed to air emissions from an incinerator may not necessarily remain in the incinerator proximity for 24 hours/day. However, if it is assumed that residential areas may be contaminated, it is likely that less mobile individuals will include those at greatest risk. Therefore it is prudent to assume that 100% of the air breathed by the most exposed individuals will be from the area of the incinerator.

See
5.2.1.2.4

5.2.1.1.5. **Relative Effectiveness of Exposure (RE)** -- RE is a unitless factor that indicates the relative toxicological effectiveness of an exposure by a given route when compared with another route. The value of RE may reflect observed or estimated differences in absorption rates between the inhalation and ingestion routes, which is then assumed to translate into a difference in the toxicant's effectiveness. For example, carbon tetrachloride and chloroform were estimated to be 40 and 65% as effective, respectively, by inhalation as by ingestion based on absorption differences (U.S. EPA, 1984e,f). In addition to route differences, RE can also reflect differences in the exposure matrix. For example, absorption of nickel ingested in water has been estimated to be 5 times that when ingested in food (U.S. EPA, 1985e). Alternatively, RE may reflect observed differences in effectiveness in some other toxicological responses based on exposure route differences. Since exposure for the air pathway is by inhalation, the RE factors applied are all with respect to the inhalation route. Therefore, the value of RE in equation 5-2 gives the relative effectiveness of the exposure route and matrix on which the RfD was based when compared with inhalation of contaminated air. Similarly, the RE factors in equation 5-3 show the relative effectiveness, with respect to the inhalation route, of each background exposure route and matrix. An RE factor should only be applied where well documented/referenced information is available on the contaminant's inhalation and oral pharmacokinetics. When such information is not available, RE is equal to 1.

5.2.1.2. CARCINOGENS -- For carcinogenic chemicals, the Agency considers the risk of cancer to be linearly related to dose (except at high dose levels) (49 FR 46298). The threshold assumption, therefore, does not hold, as risk diminishes with dose but does not become zero or background until dose becomes zero.

The decision whether to treat a chemical as a threshold- or non-threshold-acting (i.e., carcinogenic) agent depends on the weight of the evidence that it may be carcinogenic to humans. Methods for classifying chemicals as to their weight of evidence have been described by U.S. EPA (49 FR 46300-46301), and most of the chemicals that currently are candidates for sludge criteria have recently been classified in Health Assessment Documents or other reports prepared by the U.S. EPA's Office of Health and Environmental Assessment (OHEA), or in connection with the development of RMCLs for drinking water contaminants (50 FR 46947-46950). To derive values of RAC, a decision must be made as to which classifications constitute sufficient evidence for basing a quantitative risk assessment on a presumption of carcinogenicity. Chemicals in classifications A and B, "human carcinogen" and "probable human carcinogen," respectively, have usually been assessed as carcinogens, whereas those in classifications D and E, "not classifiable as to human carcinogenicity because of inadequate human and animal data" and "evidence of noncarcinogenicity for humans," respectively, have usually been assessed according to threshold effects. Chemicals classified as C, "possible human carcinogen," have received varying treatment. For example, lindane, classified by the Carcinogen Assessment Group (CAG) of the U.S. EPA as "B2-C", or between the lower range of the B category and category C, has been assessed using both the linear model for tumorigenic effects (U.S. EPA, 1980) and based on threshold effects (50 FR 46998-46999). Table 5-2 gives an illustration of these U.S. EPA classifications based on the available weight of evidence.

The use of the weight-of-evidence classification without noting the explanatory material for a specific chemical, may lead to a flawed conclusion since some of the classifications are exposure-route-dependent. Certain compounds (for example, nickel) have been shown to be carcinogenic by the inhalation route but not by ingestion. The issue of whether or not to treat an agent as carcinogenic by ingestion remains controversial for several chemicals.

If a pollutant is to be assessed according to nonthreshold, carcinogenic effects, the reference concentration in air, RAC, is derived as follows:

$$\text{Reference Air Concentration:}\quad RAC = \frac{RL \times BW}{q_1^* \times RE} - TBI \div I_a \qquad (5\text{-}4)$$

where: q_1^* = Human cancer potency ($[\text{mg/kg/day}]^{-1}$)

RL = Risk level (unitless); e.g., 10^{-5}, 10^{-6}

BW = Human body weight (kg)

RE = Relative effectiveness of inhalation exposure (unitless)

I_a = Air inhalation rate (m^3/day)

TBI = Total background intake rate of pollutant from all other sources of exposure (mg/day)

TABLE 5-2

Illustrative Categorization of Evidence Based on Animal and Human Data*

Human Evidence	Animal Evidence				
	Sufficient	Limited	Inadequate	No Data	No Evidence
Sufficient	A	A	A	A	A
Limited	B1	B1	B1	B1	B1
Inadequate	B2	C	D	D	D
No data	B2	C	D	D	E
No evidence	B2	C	D	D	E

*The above assignments are presented for illustrative purposes. There may be nuances in the classification of both animal and human data indicating that different categorizations than those given in the table should be assigned. Furthermore, these assignments are tentative and may be modified by ancillary evidence. In this regard all relevant information should be evaluated to determine if the designation of the overall weight of evidence needs to be modified. Relevant factors to be included along with the tumor data from human and animal studies include structure-activity relationships, short-term test findings, results of appropriate physiological, biochemical and toxicological observations, and comparative metabolism and pharmacokinetic studies. The nature of these findings may cause an adjustment of the overall categorization of the weight of evidence.

The RAC, in the case of carcinogens, is thought to be protective since the q_1^* is typically an upper limit value, i.e., the potency is statistically not likely to be greater and may be less. The definition and derivation of each of the parameters used to estimate RAC for carcinogens are discussed in later sections.

5.2.1.2.1. **Human Cancer Potency** (q_1^*) -- For most carcinogenic chemicals, the linearized multistage model is recommended for estimating human cancer potency from animal data (49 FR 46298). When epidemiological data are available, potency is estimated based on the observed relative risk in exposed versus nonexposed individuals, and on the magnitude of exposure. Guidelines for use of these procedures have been presented in the Federal Register (45 FR 79350-47353; 50 FR 46294-46301) and in each of a series of Health Assessment Documents prepared by OHEA; one example is U.S. EPA (1985d). The potency value normally used in risk assessments is the upper-bound estimate of the slope of the dose-response curve in the low-dose range, and it is expressed in terms of risk-per-dose, where dose is in units of mg/kg/day. Thus, q_1^* has units of $(mg/kg/day)^{-1}$. The CAG has derived potency estimates for each of the potentially carcinogenic chemicals that are currently candidates for sludge criteria. Therefore, no new effort is required to develop potency estimates to derive sludge criteria.

5.2.1.2.2. **Risk Level (RL)** -- Since by definition no "safe" level exists for exposure to nonthreshold agents, values of RAC are calculated to reflect various levels of cancer risk. If RL is set at zero, then RAC will be zero. If RL is set at 10^{-6}, RAC will be the concentration which, for lifetime exposure, is calculated to have an upper-bound cancer risk of one case in one million individuals exposed. This risk level refers to excess cancer risk, that is, over and above the background cancer risk in unexposed

RSD

individuals. By varying RL, RAC may be calculated for any level of risk in the low-dose region, for instance, $RL \leq 10^{-2}$. Specification of a given risk level on which to base regulations is a matter of policy. Therefore, it is common practice to derive criteria representing several levels of risk without specifying any level as "acceptable."

5.2.1.2.3. **Human Body Weight (BW) and Air Inhalation Rate (I_a)** -- Considerations for defining BW and I_a are similar to those stated in Section 5.2.1.1.2. The CAG assumes respective values of 70 kg and 20 m^3/day to derive unit risk estimates for air, which are potency estimates transformed to units of $(\mu g/m^3)^{-1}$. As illustrated in Table 5-1, exposures may be higher in children than in adults when the ratios of inhalation volumes to body weights are compared. However, exposure is lifelong, and therefore values of BW and I_a are usually chosen so as to be representative of adults.

5.2.1.2.4. **Relative Effectiveness of Exposure (RE)** -- RE is a unitless factor that indicates the relative toxicological effectiveness of an exposure by a given route when compared with another route. The value of RE may reflect observed or estimated differences in absorption rates between the inhalation and ingestion routes, which is then assumed to translate into a difference in the toxicant's effectiveness. For example, carbon tetrachloride and chloroform were estimated to be 40 and 65% as effective, respectively, by inhalation as by ingestion based on absorption differences (U.S. EPA, 1984e,f). In addition to route differences, RE can also reflect differences in the exposure matrix. For example, absorption of nickel ingested in water has been estimated to be 5 times that when ingested in food (U.S. EPA, 1985e). Alternatively, RE may reflect observed differences in effectiveness in some other toxicological responses based on route differences. Since exposure for the air pathway is by inhalation, the RE factors applied are all with respect to the inhalation route. Therefore, the value of RE in equation 5-4 gives the relative effectiveness of the exposure route and matrix on which the q_1* was based when compared with inhalation of contaminated air. Similarly, the RE factors in equation 5-3 show the relative effectiveness, with respect to the inhalation route, of each background exposure route and matrix. An RE factor should only be applied where well documented/referenced information is available on the contaminant's inhalation and oral pharmacokinetics. When such information is not available, RE is equal to 1.

5.2.1.2.5. Total Background Intake Rate of Pollutant (TBI) -- It is important to recognize that sources of exposure other than the sludge disposal practice may exist, and that the total exposure should be maintained below the determined cancer risk level. Other sources of exposure include background levels (whether natural or anthropogenic) in drinking water, food or air. Other types of exposure, that are due to occupation or habits such as smoking, might also be included depending on data availability and regulatory policy. These exposures are summed to estimate TBI.

Data for estimating background exposure usually are derived from analytical surveys of surface, ground or tap water, from FDA market basket surveys, and from air monitoring surveys. These surveys may report means, medians, percentiles or ranges, as well as detection limits. Estimates of TBI may be based on values representing central tendency or on upper-bound exposure situations, depending on regulatory policy. Data chosen to estimate TBI should be consistent with the value of BW. Where background data are reported in terms of a concentration in air or water, ingestion or inhalation rates applicable to adults can be used to estimate the proper daily background intake value. For certain compounds (for example, nickel) that have been shown to be carcinogenic by the inhalation route, but not by the ingestion route, the TBI should not include background exposure from the ingestion route. Thus, in such a case only background exposures from other air emission sources should be included in the TBI.

As stated previously, the TBI is the summed estimate of all possible background exposures, except exposures resulting from a sludge disposal practice. To be more exact, the TBI should be a summed total of all toxicologically effective intakes from all nonsludge exposures. To determine the effective TBI, Background Intake values (BI) for each exposure route must be divided by that routes particular relative effectiveness (RE) factor. Thus, the TBI can be mathematically derived, after all the background exposures have been determined, using the following equation:

$$TBI = \frac{BI_{(food)}}{RE_{(food)}} + \frac{BI_{(water)}}{RE_{(water)}} + \frac{BI_{(air)}}{RE_{(air)}} + \ldots + \frac{BI_{(n)}}{RE_{(n)}} \qquad (5\text{-}3)$$

where: TBI = Total background intake rate of pollutant from all other sources of exposure (mg/day)

BI = Background intake of pollutant from a given exposure route, indicated by subscript (mg/day)

RE = Relative effectiveness, with respect to inhalation exposure, of the exposure route indicated by subscript (unitless)

5.2.1.2.6. **Fraction of Inhaled Air from Contaminated Area** -- It is recognized that an individual exposed to air emissions from an incinerator may not necessarily remain in the incinerator proximity for 24 hours/day. However, if it is assumed that residential areas may be contaminated, it is likely that less mobile individuals will include those at greatest risk. Therefore, it is reasonable to assume that 100% of the air breathed by the most exposed individuals will be from the area of the incinerator.

6. EXAMPLE CALCULATION

After modeling is completed, the highest annual ground level concentrations can be identified at each of the model sites. By using the maximum allowable ambient concentrations for the pollutants of concern, calculated from the Reference Air Concentration (RAC) as described in Chapter 5, the air modeling results can be used to calculate the stack emission rates for each pollutant. This is conveniently done by simple ratios of the ambient concentrations and emission rates since the modeling results are linearly related in the model.

The modeled emission rates for each plant may be compared with the actual emissions determined by the testing of sludge incinerators to determine whether the emissions are acceptable. If the RACs are being exceeded, some type of criteria or management practice (or both) to reduce emissions will need to be developed. This process is illustrated in Figure 6-1.

6.1. STEP ONE

This example calculation is for a carcinogen in sludge being incinerated at Facility 7. The Facility 7 site is located 3/4 miles from a river and in an urban, industrialized area.

Four incinerator flue stacks (see Table 4-3) at the facility are taller than the critical height where building aerodynamic downwash would be expected to increase near-source surface concentrations. The incinerator plant building is a complex structure with varying roof height.

Using the air dispersion model, the highest concentration for the facility (under actual operating conditions) is located at the first receptor ring (104 meters) and is estimated to be 12.5 $\mu g/m^3/g/s$. Under design conditions, the highest concentration is estimated at 16.1 $\mu g/m^3$.

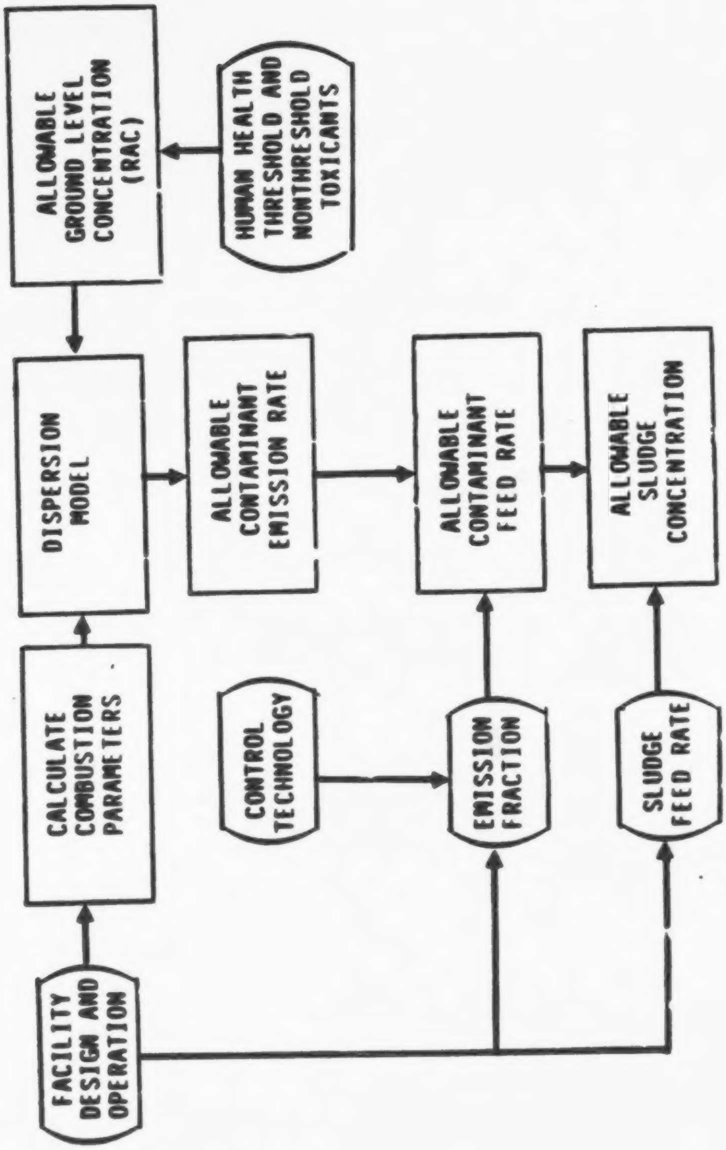

FACILITY DESIGN AND OPERATION
CALCULATE COMBUSTION PARAMETERS
DISPERSION MODEL
ALLOWABLE GROUND LEVEL CONCENTRATION (RAC)
HUMAN HEALTH THRESHOLD AND NONTHRESHOLD TOXICANTS
CONTROL TECHNOLOGY
ALLOWABLE CONTAMINANT EMISSION RATE
EMISSION FRACTION
ALLOWABLE CONTAMINANT FEED RATE
SLUDGE FEED RATE
ALLOWABLE SLUDGE CONCENTRATION

FIGURE 6-1

Criteria Derivation Approaches for Sludge Incineration

6.2. STEP TWO

The RAC for the carcinogen chlordane is derived using equation 5-4:

$$RAC = \left(\left(\frac{RL \times BW}{q_1^* \times RE}\right) - TBI\right) \div I_a$$

The risk level (RL), the body weight (BW) and the daily inhalation volume (I_a) are set for this example at 10^{-6}, 70 kg and 20 m^3/day, respectively. The relative effectiveness factor (RE) is set at 1. The human cancer potency for chlordane has been determined by the U.S. EPA to be 1.61 $(mg/kg/day)^{-1}$. Current total background intake (TBI) of chlordane from all other sources (i.e., except from incineration of sludges) has not been determined for 1986, but for illustrative purposes TBIs of 0 and 20 ng/day (20×10^{-6} mg/day) are used here to derive example RACs. Determination of an RAC for a specific incinerator site should be based on a current local assessment of TBI.

Example #1 (TBI = 0 mg/day)

$$RAC = \left(\left(\frac{10^{-6} \times 70 \text{ kg}}{1.61 \text{ (mg/kg/day)}^{-1} \times 1}\right) - 0\right) \div 20 \text{ m}^3\text{/day}$$

$$= 2.17 \times 10^{-6} \text{ mg/m}^3$$

$$= 2.17 \times 10^{-3} \text{ μg/m}^3$$

$$SC = \frac{RAC \times CF_1 \times CF_2}{DP \times FE \times FR}$$

where:

RC = Reference Air Concentration ($\mu g/m^3$)

CF_1 = Conversion factor (sec/hr)

CF_2 = Conversion factor (mg/g)

DP = Dispersion parameter ($\mu g/m^3\ [g/s]^{-1}$) (operating conditions)

FE = Fraction emitted (unitless)

FR = Feed rate [kg/hr, dry weight (DW)]

SC = Allowable sludge concentration [mg/kg, dry weight (DW)]

$$SC = \frac{2.17\times10^{-3}\ \mu g/m^3 \times 3600\ sec/hr \times 10^3\ mg/g}{12.5\ \mu g/m^3\ (g/s)^{-1} \times {}^{*}0.05 \times {}^{**}2660\ kg/hr\ DW}$$

$$= 4.7\ mg/kg\ DW$$

*The fraction emitted for this calculation assumes 95% efficiency.

**The feed rate for Facility 1 is an assumption.

Example #2 (TBI = 20 ng/day)

$$RAC = \left(\left(\frac{10^{-6} \times 70\ kg}{1.61\ (mg/kg/day)^{-1} \times 1}\right) - 20\times10^{-6}\ mg/day\right) \div 20\ m^3/day$$

$$= 1.17\times10^{-6}\ mg/m^3$$

$$= 1.17\times10^{-3}\ \mu g/m^3$$

$$SC = \frac{1.17\times10^{-3}\ \mu g/m^3 \times 3600\ sec/hr \times 10^3\ mg/g}{12.5\ \mu g/m^3\ (g/s)^{-1} \times 0.05 \times 2660\ kg/hr\ DW}$$

$$= 2.57\ mg/kg\ DW$$

7. REFERENCES

Anderson, G.E. and G.W. Lundberg. 1983. Users manual for SHEAR-A computer code for modeling human exposure and risk from multiple hazardous air pollutants in selected regions. SYS APP-83/124, Systems Applications, Inc., San Rafael, CA.

Anderson, G.E., C.S. Liu, H.Y. Holman and J.P. Killus. 1981. Human exposure to atmospheric concentration to selected chemicals. EF-156R, Systems Application, Inc., San Rafael, CA.

Astrand, P.-O. and K. Rodahl. 1977. Textbook of Work Physiology, 2nd ed. McGraw-Hill, New York, NY. (Cited in Fiserova-Bergerova, 1983)

Auer, A.H., Jr. 1978. Correlation of land use and cover with meteorological anomalies. J. Appl. Meteor. 17: 636-643.

Briggs, G.A. 1969. Plume rise. Available as TID-25075 from Clearinghouse for Federal Scientific and Technical Information, Springfield, VA.

Briggs, G.A. 1971. Some recent analysis of plume rise observations. In: Proc. 2nd Int. Clean Air Congress, Academic Press, NY.

Briggs, G.A. 1972. Chimney plumes in neutral and stable surroundings. Atm. Environ. 6: 507-510.

Briggs, G.A. 1975. Plume rise predictions. In: Lectures on Air Pollution and Environmental Impact Analyses. American Meteorological Society, Boston, MA.

Farrell, J.B. and B.V. Salotto. 1973. The effect of incineration on metals, pesticides and polychlorinated biphenyls in sewage sludge. Proc. Natl. Symp. on Ultimate Disposal of Wastewaters and Their Residuals. Sponsored by Research Triangle Universities.

Federal Register. 1974. Volume 39, p. 4308. March 8.

Fiserova-Bergerova, V, Ed. 1983. Modeling of Inhalation Exposure to Vapors: Uptake, Distribution and Elimination. Vol. II. CRC Press, Inc., Boca Raton, FL.

Fruhman, G. 1964. Title not given. Z. Exp. Med. 138: 1. (Cited in Diem and Lentner, 1970)

Furr, A.K., T.F. Parkinson, T. Wachs, C.A. Bache, W.H. Gutenmann, P.C. Wsolek, I.S. Pakkala and D.J. Lisk. 1979. Multielement analysis of municipal sewage sludge ashes. Absorption of elements by cabbage grown in sludge ash-soil mixture. Environ. Sci. Technol. 13: 1503. December.

Holzworth, G.C. 1972. Mixing heights, wind speeds and potential for urban air pollution throughout the contiguous U.S. Publ. No. AP-101. U.S. EPA, RTP, NC.

Huber, A.H. 1977. Incorporating building/terrain wake effects on stack effluents. Preprint Volume for Joint Conf. on Application of Air Pollution Meteor., American Meteorological Society, Boston, MA.

Huber, A.H. and W.H. Snyder. 1976. Building wake effects on short stack effluents. Preprint Volume for the 3rd Symp. Atmospheric Diffusion and Air Quality, American Meteorological Society, Boston, MA.

ICRP (International Commission on Radiological Protection). 1975. Report of the Task Group on Reference Man (No. 23). Pergamon Press, Ltd.

Lu, F.C. 1983. Toxicological evaluations of carcinogenic and noncarcinogens: Pros and cons of different approaches. Reg. Toxicol. Pharmacol. 3: 121-132.

NOAA (National Oceanographic and Aeronautics Agency). 1978. Climates of the U.S. Book Tower, Detroit, MI.

Turner, D.B. 1970. Workbooks of atmospheric dispersion estimates. PHS Publ. No. 999-AP-26. U.S. DHEW National Air Pollution Control Adm., Cincinnati, OH.

U.S. EPA. 1979. Industrial Source Complex (ISC) Model User's Guide, Volumes I and II. EPA 450/4-79-030 and EPA 450/4-79-031. December.

U.S. EPA. 1980. Ambient Water Quality Criteria Document for Hexachlorocyclohexane. Environmental Criteria and Assessment Office, Cincinnati, OH. EPA 440/5-80-054.

U.S. EPA. 1982. User's Instricutions for the SHORTZ and LONGZ Computer Programs, Volumes I and II. EPA 903/9-82-004A and B.

U.S. EPA. 1983. User's Network for Applied Modeling of Air Pollution (UNAMAP), Version 5 (computer programs on tape). NTIS PB 83-244368.

U.S. EPA. 1984a. Second Review of Standards of Performance for Sewage Sludge Incinerators. EPA 450/3-84-010. March.

U.S. EPA. 1984b. Project Summary: Analysis and Assessment of Incinerated Municipal Sludge Ashes and Leachates. EPA 600/S2-84-035.

U.S. EPA. 1984c. Guidelines on Air Quality Models. Revised Draft. EPA 450/2-78-027. November. OAQPS, RTP, NC.

U.S. EPA. 1984d. Mercury Health Effects Update. Health Issue Assessment. EPA 600/8-84-019F. August.

U.S. EPA. 1984e. Health Assessment Document for Carbon Tetrachloride. EPA 600/8-82-001F. Environmental Criteria and Assessment Office, Cincinnati, OH.

U.S. EPA. 1984f. Health Assessment Document for Chloroform. EPA 600/8-84-004A. Environmental Criteria and Assessment Office, Cincinnati, OH.

U.S. EPA. 1985a. Seminar Publication: Municipal Wastewater Sludge Combustion Technology. Center for Environmental Research Information, Cincinnati, OH. EPA 625/4-85/015. September.

APPENDIX C

ISCLT Model Sensitivity Analysis

SEWER SLUDGE INCINERATION:
ISCLT MODEL
SENSITIVITY ANALYSIS

by

PEI Associates, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

Contract No. 68-02-4351
Work Assignment No. 6
PN 3718-6

Work Assignment Manager
Elizabeth Southerland

U.S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER (WH 585)
401 M STREET, SW
WASHINGTON, D.C. 20460

August 1987

CONTENTS

Page

Tables iii

1. Introduction 1-1

2. Analysis Methodology 2-1

    2.1 Overview 2-1
    2.2 Dispersion modeling 2-2
    2.3 Post-processor program 2-11

3. Ambient Concentration Calculations 3-1

    3.1 Analysis scenarios 3-1
    3.2 Ambient concentrations 3-4
    3.3 Maximum allowable emissions 3-6

Appendices

A - Tabulation of Maximum Concentrations and Allowable Emissions by Case Number A-1

B - Tabulation of Maximum Allowable Concentrations and Percentage Differences by Chemical Constituent B-1

June [illegible] 1987

Out [illegible]

Check with [illegible]

TABLES

Number		Page
2-1	Options Used in ISCLT Modeling	2-4
2-2	STAR Meteorological Data Used in Sludge Incinerator Analysis	2-5
2-3	Annual Average Mixing Heights	2-7
2-4	Annual Average Temperatures	2-8
2-5	Comparison of Maximum Concentrations Derived by Use of Building Downwash With Final Plume Rise and With Distance-Dependent Plume Rise	2-11
2-6	Sludge Incinerator Chemical Constituents and Target Air Concentrations	2-12
3-1	Source Characteristics of Sludge Incinerator Cases 1 Through 6	3-3
3-2	Identification of Case Numbers 7 Through 24	3-3
3-3	Source Characteristics of Sludge Incineration Cases 25 Through 33	3-4
3-4	Maximum Normalized Concentrations for Each Case	3-5
3-5	Temporal Stratification of Maximum Concentration Estimates for Sludge Incineration at Different Sites	3-7
3-6	Spatial Stratification of Maximum Concentration Estimates for Sludge Incineration at Different Sites	3-8

SECTION 1

INTRODUCTION

Under a previous contract (No. 68-02-3870), the Source Receptor Analysis Branch (SRAB) of the Office of Air Quality Planning and Standards (OAQPS) of the U.S. Environmental Protection Agency (EPA) evaluated the long-term (annual) air quality impacts and associated human health risk for several chemical species emitted at 10 sewage sludge incinerators. Dispersion modeling techniques consistent with the Guideline on Air Quality Models (EPA-450/2-78-027R, 1986) were used to perform the analysis.

The EPA Office of Water (OW) used the results of the analysis to assess the air quality impacts and potential health risks resulting from sludge incineration. These impacts are being used to develop regulations governing the use and disposal of sludge. Currently, the proposed regulation calls for the use of dispersion modeling techniques to estimate downwind concentrations of various sludge chemical constituents. Specifically, the regulation recommends the use of the Industrial Source Complex Model in its long-term mode (ISCLT). The proposed technique calls for dispersion modeling results to be compared with Incremental Annual Air Quality Criteria concentrations, i.e., established levels based on an acceptable daily intake and a risk of one in a million persons. Comparisons with criteria levels make it possible to determine the maximum allowable concentrations of pollutants in the sewage sludge. The ambient air concentrations were assumed to affect an individual located at the point of maximum concentration [maximum exposed individual (MEI)] who inhales emissions 100 percent of the time over a 70-year life span.

Of concern to OW in the use of this approach was the sensitivity of ISCLT to various source configurations and meteorological conditions and the possibility that a detailed analysis would be required for every incinerator. For determination of analysis sensitivity, an expanded set of stack configurations and meteorological data sets were used in the ISCLT Model. For each scenario, the allowable emission rate per chemical compound was calculated both on the basis of the maximum concentration and on concentrations at other specified distances. The ratio of the scenario to base-case allowable emissions was calculated to generate percentage differences, which were used to demonstrate the degree of variation of allowable sludge concentrations resulting from site-specific factors.

SECTION 2

ANALYSIS METHODOLOGY

2.1 OVERVIEW

The maximum ambient air concentrations and subsequent maximum allowable concentrations of various chemical constituents in the sewage sludge were calculated by use of a combination of the ISCLT Model and a post-processing program. This methodology included the following steps:

- Selected base-case source configuration, site, and representative meteorological data.
- Selected appropriate ISCLT options, input values, and modeling protocol.
- Determined the need for including of building downwash.
- Performed base-case ISCLT analysis by using an emission rate of 1.0 g/s to represent any pollutant.
- Determined maximum annual concentrations at any receptor location and at downwind distances of 200, 500, and 1000 m from the ISCLT analysis.
- Used the ambient concentration estimates (allowable ambient levels) and the Incremental Annual Air Quality Criteria (IAAQC) to derive maximum allowable emission rates.
- Modeled all other scenarios (i.e., source configurations and meteorological data sets) in a similar manner and determined the maximum allowable emission rates for each chemical constituent.
- Compared the maximum allowable emission rate for each chemical and each scenario with the base case and calculated the percentage difference.
- Determined the sensitivity of the methodology to the various differences in source configuration and to the different sets of meteorological data.

The following subsections describe the two major components of the modeling analysis: 1) the ISCLT modeling, and 2) the post-processing to derive maximum allowable emissions and the percentage differences between scenarios and the base case.

2.2 DISPERSION MODELING

The modeling was performed with the ISCLT Model (EPA-450/4-86-005a, 1986), which uses meteorological data consisting of joint-frequency distributions of windspeed, wind direction, and atmospheric stability class. The ISCLT Model is a steady-state, Gaussian plume, atmospheric dispersion model that is applicable to multiple point, area, and volume emission sources; arrays of receptors; and long-term averaging periods (quarterly, annual, etc.). The ISCLT Model is recognized by the Guideline on Air Quality Models as a suitable model for complex sources in simple terrain and for fugitive emission sources. In this analysis, the current UNAMAP 6 version of the model was used for all calculations.

It was assumed that emissions are gaseous and that particulate emissions will be less than about 10 to 15 μm. It was further assumed that the effluent characteristics of each chemical constituent are identical. Thus, a generalized pollutant was modeled, and results were subsequently prorated to determine maximum allowable emissions (based on a comparison of prorated concentrations with each IAAQC).

2.2.1 ISCLT Input Options

The ISCLT Model required that multiple input options and variables be specified. In all cases, the selected options were as close to those of the previous EPA analysis (Contract No. 68-02-3870) as possible, especially with regard to the base case (defined in detail in Section 3). For the most part, these options (presented in Table 2-1) are consistent with EPA-recommended selections. Minor differences between the Table 2-1 options and those in the previous EPA analysis resulted from the use of the UNAMAP 5 version of the ISCLT Model in the previous analysis. Individual print options (and other specifications not discussed herein) are presented for all cases in the analysis in the ISCLT Model outputs in Appendix C.

2.2.2 Urban/Rural Selection

An urban mode was selected as being the most consistent with and representative of typical current and future locations of sludge incinerators. Where the sludge incinerators are sited also enters into the selection of mixing heights and the choice of wind profile exponents. For all analyses herein, the Urban Mode 3 was selected. This mode specifies the use of the McElroy-Pooler dispersion coefficients in ISCLT, which are currently part of the UNAMAP 6 version and which EPA recommends for use.

2.2.3 Meteorological Data

Meteorological data were used by the ISCLT Model in the STAR (STability ARray) format, which consists of joint-frequency distributions of windspeed, wind direction, and atmospheric stability class. These data were generated from surface meteorological data available from National Weather Service offices that generally are located at major commercial airports. All STAR distributions were previously prepared. For this study, the location of the base case selected for analysis of all source configurations was Hartsfield Airport, Atlanta, Georgia.

To determine the potential variability of ambient pollutant concentrations due to meteorological variability, the EPA-OW selected 19 alternate sites for analysis of the base-case stack configuration. Table 2-2 presents both the selcted sites and the sites actually used in the analysis. The

TABLE 2-1. OPTIONS USED IN ISCLT MODELING

Option description
Wind direction, windspeed, and Pasquill-Gifford (P-G) stability data were input in the form of STAR data.
Annual mixing heights for each site were obtained from the Holzworth mixing height study (AP-101, 1972) and were input by stability class according to ISCLT guidance.
Annual ambient air temperatures were obtained from local climatological data summaries and were input by stability class according to ISCLT guidance.
The following wind profile exponents were used for Stability Classes A through F: Urban applications - 0.15, 0.15, 0.20, 0.25, 0.30, 0.30
The midpoint of the first windspeed class for the STAR input data was specified to be 1.5 meters per second instead of the ISCLT default 0.75 meter per second.
Vertical potential temperature gradients and entrainment coefficients were ISCLT default values.
The Urban Mode 3 was used for all sites.
Plume rise was specified to be final.
Wind system reference measurement height was set to 10 meters.
Terrain effects were not used.
A polar coordinate receptor grid was used.
Stack sources were modeled, and unit (1 gram per second) emissions remained constant in time.
Two stacks located 2.5 m apart were assumed in each scenario.
Building aerodynamic downwash analysis was performed.
Program control parameters, receptors, and source input data were output.
Annual concentrations were calculated and output.

TABLE 2-2. STAR METEOROLOGICAL DATA USED IN SLUDGE INCINERATOR ANALYSIS

EPA-OW selected sites	Sites used in analysis	Years of composite distribution
Atlanta, Georgia[a]	Atlanta, Georgia	1959-1963
Boston, Massachusetts[b]	Boston, Massachusetts	1966-1970
Windsor Locks, Connecticut[b]	Hartford, Connecticut	1955-1964
Newark, New Jersey[b]	Teterboro, New Jersey	1952-1956
San Juan, Puerto Rico[c]	San Juan, Puerto Rico	1979-1983
Pittsburgh, Pennsylvania[b,d]	Pittsburgh, Pennsylvania	1974-1975
Charleston, South Carolina[b]	Savannah, Georgia	1966-1970
Birmingham, Alabama[b]	Anniston, Alabama	1949-1954
Detroit, Michigan[b]	Detroit, Michigan	1970-1974
Dayton, Ohio[b]	Dayton, Ohio	1970-1974
Houston, Texas[b]	Houston, Texas	1971-1975
Dallas, Texas[b]	Dallas, Texas	1969-1973
Albuquerque, New Mexico[b]	Santa Fe, New Mexico	1950-1954
Kansas City, Kansas[b]	Topeka, Kansas	1963-1972
Denver, Colorado[b]	Denver, Colorado	1970-1974
Gillette, Wyoming[c]	Miles City, Montana	1971-1975
Los Angeles, California[b]	Los Angeles, California	1955-1964
Reno, Nevada[b]	Reno, Nevada	1960-1964
Seattle-Tacoma, Washington[b]	Tacoma, Washington	1966-1970
Fairbanks, Alaska	None available	-

[a] Base case; source of data - SAI.

[b] Source of data - Human Exposure Model system on EPA-NCC.

[c] PEI data files.

[d] Only two years readily available.

required quick turnaround time for the technical work to be completed necessitated the substitution of several sites for those requested because STAR data were more readily available. Inasmuch as the analysis objective was to examine concentration variability due to meteorological differences across all 10 EPA Regions, the substitutions should provide as in-depth an analysis as was originally planned. The source of most of the STAR distributions was the meteorological data files used by the EPA Human Exposure Model (EPA-450/5-86-001, 1986), available through the National Computing Center in Research Triangle Park, North Carolina. The only modification required was the recombining of the vertical stability class day-night distributions into one neutral class as required by ISCLT.

Two other meteorological inputs required by the ISCLT Model were the annual average mixing heights and temperatures. Based on the techniques provided in the ISCLT user's manual for an urban area, mixing heights were derived from Holzworth's mixing height climatology (AP-101, 1972), and temperatures were derived from local climatological data summaries. Locations for these data tabulations were made on the basis of the base-case site (Atlanta, Georgia) and the other sites selected for analysis.

Table 2-3 presents the stability-class-specific mixing heights used in the analysis for each site. Similarly, Table 2-4 presents the stability-class-specific temperatures used in the ISCLT modeling.

2.2.4 Receptor Locations

For determination of the location of maximum ambient concentrations, receptors were placed as close as 50 m from the sludge incinerator stacks. This was deemed a reasonably representative distance between an incinerator stack and the facility property boundary at which a maximum exposed individual was assumed to be located. The receptor grid consisted of concentric circles

TABLE 2-3. ANNUAL AVERAGE MIXING HEIGHTS

(m)

Site	Atmospheric stability class					
	A	B	C	D	E	F
Boston, Massachusetts	1650	1100	1100	875	650	650
Hartford, Connecticut	1815	1210	1210	953	695	695
Teterboro, New Jersey	1943	1295	1295	1055	815	815
San Juan, Puerto Rico	1000	1000	1000	950	900	900
Pittsburgh, Pennsylvania	2268	1512	1512	1011	510	510
Savannah, Georgia	1995	1330	1330	851	371	371
Anniston, Alabama	2265	1510	1510	948	385	385
Detroit, Michigan	1800	1200	1200	860	520	520
Dayton, Ohio	2076	1384	1384	930	476	476
Houston, Texas	1838	1225	1225	875	525	525
Dallas, Texas	2235	1490	1490	988	485	485
Santa Fe, New Mexico	4182	2788	2788	1637	485	485
Topeka, Kansas	1965	1310	1310	868	425	425
Denver, Colorado	3815	2543	2543	1406	268	268
Miles City, Montana	3053	2035	2035	1188	340	340
Los Angeles, California	1515	1010	1010	780	550	550
Reno, Nevada	2520	1680	1680	1040	400	400
Seattle-Tacoma, Washington	1763	1175	1175	940	705	705

TABLE 2-4. ANNUAL AVERAGE TEMPERATURES (K)

Site	Atmospheric stability class					
	A	B	C	D	E	F
Boston, Massachusetts	288	288	288	284	280	280
Hartford, Connecticut	288	288	288	283	277	277
Teterboro, New Jersey	290	290	290	285	280	280
San Juan, Puerto Rico	303	303	303	299	295	295
Pittsburgh, Pennsylvania	289	289	289	283	278	278
Savannah, Georgia	297	297	297	291	285	285
Anniston, Alabama	296	296	296	290	284	284
Detroit, Michigan	288	288	288	283	278	278
Dayton, Ohio	289	289	289	284	279	279
Houston, Texas	300	300	300	294	287	287
Dallas, Texas	298	298	298	292	285	285
Santa Fe, New Mexico	294	294	294	287	279	279
Topeka, Kansas	291	291	291	286	280	280
Denver, Colorado	291	291	291	283	275	275
Miles City, Montana	288	288	288	280	273	273
Los Angeles, California	294	294	294	290	285	285
Reno, Nevada	292	292	292	283	273	273
Seattle-Tacoma, Washington	288	288	288	284	279	279

with receptors located at intervals of 22.5 degrees, starting at north and proceeding clockwise around the compass. A concentric circle of receptors was located at downwind distances of 50, 100, 200, 300, 500, 700, 1,000, 1,500, 2,000, 3,000, 5,000, 7,000, 10,000, 12,500, 15,000, and 20,000 m. The number of receptors used totaled 256. Review of the stack configurations under analysis indicates that this grid should adequately distribute receptors to ascertain maximum concentrations for each case. Terrain was assumed to be level in these analyses.

2.2.5 Building Downwash

For each scenario, the incinerator stacks were assumed to be situated adjacent to a building housing the incinerators, sludge-moving equipment, and other facility processes. For every scenario, the building was assumed to have the following dimensions:

Height = H_b = 5.5 m

Width = H_w = 23.5 m

Length = H_l = 31.7 m

The ISCLT Model incorporates a building downwash algorithm that the Guideline on Air Quality Models recommends for use when a modeling situation is appropriate for such treatment. In the base case, the ratio of stack height to building height was such that inclusion of building downwash was appropriate. The building dimensions were included in all subsequent scenarios to allow the ISCLT Model to determine the need for building downwash treatment. An internal ISCLT calculation makes this determination on the basis of the ratio of stack height plus momentum plume rise to the lesser of the building height or width.

The ISCLT Model requires the input of the building height and width (the model assumes a square building). The user instructions for ISCLT further require input of an effective width of a square building of equal horizontal area to the actual building. In keeping with the recommendation of the EPA "Regional Workshops on Air Quality Modeling: A Summary Report" (EPA-450/4-82-015, revised August 1983), a slightly modified procedure was used. This procedure involved finding the maximum projected building width (in this case, the diagonal of 39.5 m, as defined by Good Engineering Practice stack height techniques) and using this as the diameter of a cylindrical building (ISCLT internally assumes a cylindrical building; i.e., the building can only have one width downwind of the stack for all wind directions). The area of a cylindrical building of this diameter is used to determine the width of an equivalent square area. In this analysis, the square equivalent width was input to ISCLT to determine the width, which equaled 35.0 m in this case.

Because of the possible critical nature of downwash calculations in the analysis, two sets of test runs were performed for three different stack heights. In one case, the final plume rise was used. In the other case, the distance-dependent plume rise was used. Results of this analysis are presented in Table 2-5. The results indicated slightly higher (about 5 percent) concentrations when the final plume rise was used was used; therefore, final plume rise was used in the base case and all subsequent scenarios.

TABLE 2-5. COMPARISON OF MAXIMUM CONCENTRATIONS DERIVED BY USE OF BUILDING DOWNWASH WITH FINAL PLUME RISE AND WITH DISTANCE-DEPENDENT PLUME RISE

Case No.[a]	Stack height, m	Maximum concentration, μg/m³ Final plume rise	Maximum concentration, μg/m³ Distance-dependent plume rise
Base case	7.6	110.6	107.5
29	19	14.6	14.1
33	61	1.12	0.99

[a] See Subsection 3.1.

2.3 POST-PROCESSOR PROGRAM

A post-processor program was developed for this analysis for tabulation of maximum concentrations and maximum allowable emissions for each chemical constituent and each scenario. The program read the maximum concentrations from the ISCLT Model analysis for each scenario and compared these values with the allowable ambient concentration levels (shown in Table 2-6) for each chemical constituent. Because an emission rate of 1.0 g/s was used in the ISCLT analysis, calculation of an allowable emission rate was based on the assumption that the air concentration was directly proportional to emissions.

$$\frac{x_{all}}{x_{ISC}} = \frac{Q_{all}}{1\ g/s}$$

where x_{all} = the Table 2-6 allowable concentration ($\mu g/m^3$)

x_{ISC} = the ISCLT-estimated concentration ($\mu g/m^3$)

Q_{all} = the allowable emission rate

The maximum concentration at all receptors and the maximum concentrations at 200, 500, and 1000 m, respectively, were used to calculate an allowable emission rate for each chemical at each distance. Tables of these results are presented in Appendix A.

TABLE 2-6. SLUDGE INCINERATOR CHEMICAL CONSTITUENTS[a] AND TARGET AIR CONCENTRATION

Sludge chemical constituent	Incremental annual air quality criteria, $\mu g/m^3$
Aldrin	0.00022
Arsenic	0.00023
Benzo(a)pyrene	0.00057
Beryllium	0.00042
Bis(2 ethyl hexyl)phthalate	0.24800
Cadmium	0.00057
Carbon tetrachloride	0.02700
Chromium (+6)	0.00009
Chloroform	0.04300
Chlorodane	0.00270
Dieldrin	0.00018
Lead	0.15000
Mercury	0.18000
Nickel	0.00330
PCB's	0.00046
Toxaphene	0.00310
Vinyl chloride	0.14000

[a] Calculated based on Acceptable Daily Intakes or other EPA-OW derived values.

A second part of the post-processor program entailed the development of comparisons of each scenario with the base case for each chemical. For these comparisons, the ratio of the scenario's maximum allowable emissions to the base-case allowable emissions was expressed as a percentage. Appendix B contains the results of these analyses. Each table presents information pertaining to one chemical, all scenarios, and at each of four downwind distances (maximum, 200, 500, and 1000 m).

A second set of results to show the percentage differences in maximum allowable emissions was generated in LOTUS-1,2,3^R format on a floppy diskette and provided to EPA-OW. The Agency subsequently used these to calculate allowable sludge concentrations.

SECTION 3

AMBIENT CONCENTRATION CALCULATIONS

3.1 ANALYSIS SCENARIOS

Four sets of scenarios were analyzed with the ISCLT Model, as described in Section 2:

- Base case
- Cases 1 through 6, variable source configurations
- Cases 7 through 24, variable meteorological sites
- Cases 25 through 33, variable stack heights

3.1.1 Base Case

The scenario used to establish a base case was taken from a July 1986 analysis entitled "Sludge Incinerator Air Quality Modeling," which was performed under Contract No. 68-02-3870. The conditions of this scenario were as follows:

Number of stacks = 2
Stack height = 7.6 m
Stack diameter = 0.51 m
Exit velocity = 7.0 m/s
Gas temperature = 311 K
Building height = 5.5 m
Building length = 31.7 m
Building width = 23.5 m
Unit emissions = 1.0 g/s per stack
STAR data = Atlanta, Georgia, 1959-1963
Spatial separation = 2.5 m

Factors pertaining to the base case include the treatment of building downwash, the spatial separation of the two stacks by 2.5 m on an east-west line, and the use of a data set identical to that used in the previous EPA study. Because each stack was assumed to emit 1 g/s, the resultant concentrations were first divided by a factor of 2 in the post-processor to allow the post-processor programs to function properly.

3.1.2 Cases 1 Through 6

Six sludge incinerator cases were tested with variable stack heights, stack diameters, stack gas exit velocities, and gas temperatures to correspond to possible control cases. The overall effect of these variations was the calculation of greater plume rise heights than the base case and, subsequently, lower ambient impacts at greater distances downwind. Table 3-1 presents the stack characteristics for these cases.

3.1.3 Cases 7 Through 24

An additional 18 geographical sites were selected for analysis to test the sensitivity of the ISCLT modeling of the sludge incinerators to the variability of different meteorological regimes. The sites selected for analysis (presented in Table 2-2) represent Cases 7 through 24 in this analysis. The base-case sources were used throughout these scenarios, and the STAR frequency distributions, the mixing heights, and the ambient temperatures varied by site. Because the order of sites was modeled somewhat differently from that presented in Table 2-2, Table 3-2 presents the case number and site location used in the analysis.

3.1.4 Cases 25 through 33

An additional nine source configurations were tested to investigate the sensitivity of the ambient concentration estimates to other stack parameters.

TABLE 3-1. SOURCE CHARACTERISTICS OF SLUDGE INCINERATOR CASES 1 THROUGH 6

Case No.	Case description[a]	Stack height, m	Stack diameter, m	Exit velocity, m/s	Gas temperature, K
1	Best-case wet scrubber	76	5.11	5.7	315
2	Best-case dry air pollution control	76	5.11	8.6	477
3	Medium-case wet scrubber	21.8	0.91	7.7	308
4	Medium-case dry air pollution control	21.8	0.91	11.9	477
5	Low-case wet scrubber	9.2	0.46	10.1	308
6	Low-case dry air pollution	9.2	0.46	15.6	477

[a] Base case used for the following:
STAR meteorology = Atlanta, Georgia, 1959-1963
Building height = 5.5 m
Building length = 31.7 m
Building width = 23.5 m
Emission rate = 1.0 g/s per stack

TABLE 3-2. IDENTIFICATION OF CASE NUMBERS 7 THROUGH 24

Case No.	Site
7	Boston, Massachusetts
8	Hartford, Connecticut
9	Teterboro, New Jersey
10	Pittsburgh, Pennsylvania
11	Savannah, Georgia
12	Anniston, Alabama
13	Dayton, Ohio
14	Houston, Texas
15	Dallas, Texas
16	Santa Fe, New Mexico
17	Topeka, Kansas
18	Detroit, Michigan
19	San Juan, Puerto Rico
20	Miles City, Montana
21	Denver, Colorado
22	Los Angeles, California
23	Reno, Nevada
24	Tacoma, Washington

Table 3-3 presents the stack characteristics for Cases 25 through 33. The stacks were selected by EPA-OW to be representative of existing facilities.

TABLE 3-3. SOURCE CHARACTERISTICS OF SLUDGE INCINERATOR CASES 25 THROUGH 33

Case No.[a]	Stack height, m	Stack diameter, m	Exit velocity, m/s
25	11	0.9	4.3
26	13	0.9	4.9
27	15	0.9	4.3
28	17	0.5	0.4
29	19	0.9	7.8
30	23	0.6	7.2
31	31	1.5	6.0
32	47	2.4	12.1
33	61	3.0	5.5

[a] Base case used for the following:
STAR meteorology = Atlanta, Georgia, 1959-1963
Building height = 5.5 m
Building length = 31.7 m
Building width = 23.5 m
Emission rate = 1.0 g/s per stack

3.2 AMBIENT CONCENTRATIONS

Table 3-4 presents the results of the ISCLT Model analysis for each case study and the base case. Results include the maximum estimated concentrations for the overall receptor grid as well as the concentrations at each downwind distance of 200, 500, and 1000 m. As shown, the ISCLT calculated a wide range in maximum concentrations (e.g., 0.13 to 68.8 $\mu g/m^3$) for Cases 1 through 6. This variation was due to the differences in stack parameters; stack heights ranged from 9.2 to 76 m, stack diameters ranged from 0.46 to 5.11 m, exit velocities varied by a factor of 2, and gas temperatures ranged from 308 to 477 K (which subsequently affects the height of the plume above ground level and the downwind distance to where the plume impacts ground-level ambient air).

U3 is more conservative

TABLE 3-4. MAXIMUM NORMALIZED CONCENTRATIONS FOR EACH CASE[a]

Case No.	Maximum concentration		Maximum concentration at specific distances, µg/m³		
	Concentration, µg/m³	Distance, m	200 m	500 m	1000 m
Base case	3.12 110.0 56.8 113.6	50	21.1	5.42	1.77
1	0.36 42.3 R	500	0.030	0.36	0.25
2	0.13	1000	0.0001	0.07	0.13
3	11.4	100	7.95	3.21	1.27
4	3.90	200	3.90	2.06	1.00
5	68.8	50	19.2	5.36	1.77
6	25.4	100	11.8	4.16	1.59
7	80.5	50	10.2	2.29	0.72
8	125.0	50	26.1	6.66	2.14
9	95.7	50	23.3	6.93	2.37
10	107.0	50	19.1	4.70	1.49
11	92.0	50	18.7	5.27	1.77
12	129.0	50	36.0	10.5	3.57
13	99.6	50	17.4	4.38	1.41
14	88.0	50	20.3	5.59	1.85
15	149.0	50	22.8	5.44	1.72
16	90.3	50	17.1	4.42	1.46
17	128	50	22.9	5.68	1.81
18	103	50	16.9	4.11	1.31
19	185	50	32.6	9.62	3.28
20	90.5	50	18.1	4.64	1.53
21	4/3 132	50	30.2	8.93	3.10
22	96.8 R 132 — 191	50	32.8	7.86	2.47
23	82.8	50	21.8	7.10	2.50
24	148	50	53.5	15.4	5.18
25	55.0	50	16.6	4.89	1.67
26	30.0	50	13.2	4.62	1.61
27	25.2	100	12.2	4.37	1.54
28	28.7	100	17.5	5.11	1.61
29	14.6	100	8.89	3.48	1.34
30	11.7	100	8.21	3.40	1.29
31	4.87	200	4.87	2.12	0.97
32	1.37	300	1.05	1.02	0.54
33	1.12	300	0.74	0.87	0.46

---

[a] Emissions equal to 1.0 g/s per stack.

Cases 7 through 24 do not show as significant a variation as do Cases 1 through 6. Maximum concentrations ranged from a low of 80.5 $\mu g/m^3$ (Boston) to a high of 191 $\mu g/m^3$ (Los Angeles), which indicates that the analysis is less sensitive to the meteorological data than to source parameters. Tables 3-5 and 3-6 present additional analysis of the meteorological cases. Table 3-5 stratifies the sites temporally and Table 3-6 stratifies the sites by location. As shown, the sites with longer periods of record tended to have higher average concentrations. The sites with data from the late 1960's were lower than before 1964 or after 1970. Spatially comparing the results (Table 3-6) shows that Eastern sites were generally the lowest and Midwest and South the highest. These results are illustrative of the wide variation resulting from different meteorological regimes and periods of data collection.

Cases 25 through 33, where changes in stack height were the predominant feature, show a greater variation in concentration estimates than the meteorological scenarios. Maximum concentrations ranged from a high of 55.0 $\mu g/m^3$ for Case 25 (stack height equals 11 m) to 1.12 $\mu g/m^3$ for Case 33 (stack height equals 61 m).

3.3 MAXIMUM ALLOWABLE EMISSIONS

The estimated concentrations presented in Table 3-4 were used with the Incremental Annual Air Quality Criteria (Table 2-5) to back-calculate the maximum allowable emissions for each chemical and for each scenario. The percentage difference between the maximum allowable emission for each case and each scenario was also calculated to determine the sensitivity of the results to combinations of factors. These results are presented in Appendices A and B for each case and for each chemical, respectively.

TABLE 3-5. TEMPORAL STRATIFICATION OF MAXIMUM CONCENTRATION ESTIMATES FOR SLUDGE INCINERATION AT DIFFERENT SITES

		Maximum concentration for specified time period, µg/m³			
Case No.	Site	More than 10 years of data	Years up to and including 1964	Years from 1965-1970	Years after 1970
7	Boston, Massachusetts	125.0	125.0	80.5	-
8	Hartford, Connecticut	-	95.7	-	-
9	Teterboro, New Jersey	-	-	-	-
10	Pittsburgh, Pennsylvania	-	-	-	107.0
11	Savannah, Georgia	-	-	92.0	-
12	Anniston, Alabama	-	129.0	-	-
13	Dayton, OHio	-	-	-	99.6
14	Houston, Texas	-	-	-	88.0
15	Dallas, Texas	-	-	-	149.0
16	Santa Fe, New Mexico	-	90.3	-	-
17	Topeka, Kansas	128.0	-	128.0	-
18	Detroit, Michigan	-	-	-	103
19	San Juan, Puerto Rico	-	-	-	185
20	Miles City, Montana	-	-	-	90.5
21	Denver, Colorado	-	-	-	132
22	Los Angeles, California	191.0	191.0	-	-
23	Reno, Nevada	-	82.8	-	-
24	Tacoma, Washington	-	-	-	148
	Concentration average	148	119.0	100.2	122.5

TABLE 3-6. SPATIAL STRATIFICATION OF MAXIMUM CONCENTRATION ESTIMATES FOR SLUDGE INCINERATION AT DIFFERENT SITES

Case No.	Site	Maximum concentration by approximate site location, μg/m³				
		East	Midwest	West	North	South
7	Boston, Massachusetts	80.5	-	-	80.5	-
8	Hartford, Connecticut	125.0	-	-	125.0	-
9	Teterboro, New Jersey	95.7	-	-	95.7	-
10	Pittsburgh, Pennsylvania	-	107.0	-	107.0	-
11	Savannah, Georgia	92.0	-	-	-	92.0
12	Anniston, Alabama	-	129.0	-	-	129.0
13	Dayton, Ohio	-	99.6	-	99.6	-
14	Houston, Texas	-	-	88.0	-	88.0
15	Dallas, Texas	-	-	149.0	-	149.0
16	Santa Fe, New Mexico	-	-	90.3	-	-
17	Topeka, Kansas	-	128	-	-	-
18	Detroit, Michigan	-	103	-	103	-
20	Miles City, Montana	-	-	90.5	-	-
21	Denver, Colorado	-	-	132	-	-
22	Los Angeles, California	-	-	191	-	-
23	Reno, Nevada	-	-	82.8	-	-
24	Tacoma, Washington	-	-	148	-	-
	Average	98.3	113.3	109	101.8	114.5

APPENDIX A

TABULATION OF MAXIMUM CONCENTRATIONS AND ALLOWABLE EMISSIONS BY CASE NUMBER

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: ISCBASEU.OUT

BASECASE

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	110.55	21.12	5.43	1.77
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.398E-05	0.208E-04	0.811E-04	0.249E-03
Arsenic	0.416E-05	0.218E-04	0.847E-04	0.260E-03
Benzo(A)pyrene	0.103E-04	0.540E-04	0.210E-03	0.644E-03
Beryllium	0.760E-05	0.398E-04	0.155E-03	0.475E-03
Bis(2 ethyl Hexyl)	0.449E-02	0.235E-01	0.914E-01	0.280E+00
Cadmium	0.103E-04	0.540E-04	0.210E-03	0.644E-03
Carbon Tet.	0.488E-03	0.256E-02	0.995E-02	0.305E-01
Chromium +6	0.163E-05	0.852E-05	0.332E-04	0.102E-03
Chloroform	0.778E-03	0.407E-02	0.158E-01	0.486E-01
Chlordane	0.488E-04	0.256E-03	0.995E-03	0.305E-02
Dieldrin	0.326E-05	0.170E-04	0.663E-04	0.203E-03
Lead	0.271E-02	0.142E-01	0.553E-01	0.170E+00
Mercury	0.326E-02	0.170E-01	0.663E-01	0.203E+00
Nickel	0.597E-04	0.313E-03	0.122E-02	0.373E-02
PCBs	0.832E-05	0.436E-04	0.169E-03	0.520E-03
Toxaphene	0.561E-04	0.294E-03	0.114E-02	0.350E-02
Vinyl Chloride	0.253E-02	0.133E-01	0.516E-01	0.158E+00

(a) The maximum distance equals 50.000 meters.

7/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

ILE USED: ISCTST1U.OUT

CASE 1

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	0.36	0.03	0.36	0.25
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.121E-02	0.145E-01	0.121E-02	0.173E-02
Arsenic	0.126E-02	0.151E-01	0.126E-02	0.180E-02
Benzo(A)pyrene	0.313E-02	0.375E-01	0.313E-02	0.447E-02
Beryllium	0.231E-02	0.277E-01	0.231E-02	0.329E-02
Bis(2 ethyl Hexyl)	0.136E+01	0.163E+02	0.136E+01	0.195E+01
Cadmium	0.313E-02	0.375E-01	0.313E-02	0.447E-02
Carbon Tet.	0.148E+00	0.178E+01	0.148E+00	0.212E+00
Chromium +6	0.495E-03	0.593E-02	0.495E-03	0.706E-03
Chloroform	0.236E+00	0.283E+01	0.236E+00	0.337E+00
Chlordane	0.148E-01	0.178E+00	0.148E-01	0.212E-01
Dieldrin	0.989E-03	0.119E-01	0.989E-03	0.141E-02
Lead	0.824E+00	0.988E+01	0.824E+00	0.118E+01
Mercury	0.989E+00	0.119E+02	0.989E+00	0.141E+01
Nickel	0.181E-01	0.217E+00	0.181E-01	0.259E-01
PCBs	0.253E-02	0.303E-01	0.253E-02	0.361E-02
Toxaphene	0.170E-01	0.204E+00	0.170E-01	0.243E-01
Vinyl Chloride	0.770E+00	0.922E+01	0.770E+00	0.110E+01

(a) The maximum distance equals 500.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 1	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.121E-02	30282.7
Arsenic	0.416E-05	0.126E-02	30289.3
Benzo(A)pyrene	0.103E-04	0.313E-02	30317.5
Beryllium	0.760E-05	0.231E-02	30275.4
Bis(2 ethyl Hexyl)	0.449E-02	0.136E+01	30259.3
Cadmium	0.103E-04	0.313E-02	30317.5
Carbon Tet.	0.488E-03	0.148E+00	30311.0
Chromium +6	0.163E-05	0.495E-03	30248.8
Chloroform	0.778E-03	0.236E+00	30279.1
Chlordane	0.488E-04	0.148E-01	30311.0
Dieldrin	0.326E-05	0.989E-03	30248.8
Lead	0.271E-02	0.824E+00	30323.4
Mercury	0.326E-02	0.989E+00	30248.8
Nickel	0.597E-04	0.181E-01	30282.7
PCBs	0.832E-05	0.253E-02	30289.3
Toxaphene	0.561E-04	0.170E-01	30272.8
Vinyl Chloride	0.253E-02	0.770E+00	30315.4

7/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

ILE USED: ISCTST2U.OUT

CASE 2

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	0.13	0.00	0.07	0.13
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.336E-02	0.411E+01	0.625E-02	0.336E-02
Arsenic	0.351E-02	0.430E+01	0.653E-02	0.351E-02
Benzo(A)pyrene	0.871E-02	0.107E+02	0.162E-01	0.871E-02
Beryllium	0.642E-02	0.785E+01	0.119E-01	0.642E-02
Bis(2 ethyl Hexyl)	0.379E+01	0.464E+04	0.704E+01	0.379E+01
Cadmium	0.871E-02	0.107E+02	0.162E-01	0.871E-02
Carbon Tet.	0.413E+00	0.505E+03	0.767E+00	0.413E+00
Chromium +6	0.138E-02	0.168E+01	0.256E-02	0.138E-02
Chloroform	0.657E+00	0.804E+03	0.122E+01	0.657E+00
Chlordane	0.413E-01	0.505E+02	0.767E-01	0.413E-01
Dieldrin	0.275E-02	0.336E+01	0.511E-02	0.275E-02
Lead	0.229E+01	0.280E+04	0.426E+01	0.229E+01
Mercury	0.275E+01	0.336E+04	0.511E+01	0.275E+01
Nickel	0.504E-01	0.617E+02	0.937E-01	0.504E-01
PCBs	0.703E-02	0.860E+01	0.131E-01	0.703E-02
Toxaphene	0.474E-01	0.579E+02	0.880E-01	0.474E-01
Vinyl Chloride	0.214E+01	0.262E+04	0.398E+01	0.214E+01

(a) The maximum distance equals 1000.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 2	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.336E-02	84363.6
Arsenic	0.416E-05	0.351E-02	84382.1
Benzo(A)pyrene	0.103E-04	0.871E-02	84460.5
Beryllium	0.760E-05	0.642E-02	84343.4
Bis(2 ethyl Hexyl)	0.449E-02	0.379E+01	84298.6
Cadmium	0.103E-04	0.871E-02	84460.5
Carbon Tet.	0.488E-03	0.413E+00	84442.3
Chromium +6	0.163E-05	0.138E-02	84269.4
Chloroform	0.778E-03	0.657E+00	84353.8
Chlordane	0.488E-04	0.413E-01	84442.3
Dieldrin	0.326E-05	0.275E-02	84269.4
Lead	0.271E-02	0.229E+01	84477.0
Mercury	0.326E-02	0.275E+01	84269.4
Nickel	0.597E-04	0.504E-01	84363.6
PCBs	0.832E-05	0.703E-02	84382.1
Toxaphene	0.561E-04	0.474E-01	84336.3
Vinyl Chloride	0.253E-02	0.214E+01	84454.7

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

ILE USED: ISCTST3U.OUT

CASE 3

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	11.38	7.95	3.21	1.27
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.387E-04	0.554E-04	0.137E-03	0.347E-03
Arsenic	0.404E-04	0.579E-04	0.143E-03	0.363E-03
Benzo(A)pyrene	0.100E-03	0.143E-03	0.355E-03	0.899E-03
Beryllium	0.738E-04	0.106E-03	0.261E-03	0.662E-03
Bis(2 ethyl Hexyl)	0.436E-01	0.624E-01	0.154E+00	0.391E+00
Cadmium	0.100E-03	0.143E-03	0.355E-03	0.899E-03
Carbon Tet.	0.475E-02	0.679E-02	0.168E-01	0.426E-01
Chromium +6	0.158E-04	0.226E-04	0.560E-04	0.142E-03
Chloroform	0.756E-02	0.108E-01	0.268E-01	0.678E-01
Chlordane	0.475E-03	0.679E-03	0.168E-02	0.426E-02
Dieldrin	0.316E-04	0.453E-04	0.112E-03	0.284E-03
Lead	0.264E-01	0.377E-01	0.933E-01	0.236E+00
Mercury	0.316E-01	0.453E-01	0.112E+00	0.284E+00
Nickel	0.580E-03	0.830E-03	0.205E-02	0.520E-02
PCBs	0.809E-04	0.116E-03	0.286E-03	0.725E-03
Toxaphene	0.545E-03	0.780E-03	0.193E-02	0.489E-02
Vinyl Chloride	0.246E-01	0.352E-01	0.871E-01	0.221E+00

(a) The maximum distance equals 100.000 meters.

```
 --------------------------------------------------------------------------
  POLLUTANT              :  BASE CASE          :   TESTCASE NO.  3
                         :  ALLOWABLE          :___________________________
                         :  EMISSION           :  EMISSION   :   PERCENT
 ________________________:__RATE, g/s__________:__RATE, g/s__:_DIFFERENCE___
 __Aldrin________________:____0.398E-05________:__0.387E-04__:____871.6_____
 __Arsenic_______________:____0.416E-05________:__0.404E-04__:____871.8_____
 __Benzo(A)pyrene________:____0.103E-04________:__0.100E-03__:____872.7_____
 __Beryllium_____________:____0.760E-05________:__0.738E-04__:____871.3_____
 __Bis(2 ethyl Hexyl)____:____0.449E-02________:__0.436E-01__:____870.8_____
 __Cadmium_______________:____0.103E-04________:__0.100E-03__:____872.7_____
 __Carbon Tet.___________:____0.488E-03________:__0.475E-02__:____872.5_____
 __Chromium +6___________:____0.163E-05________:__0.158E-04__:____870.5_____
 __Chloroform____________:____0.778E-03________:__0.756E-02__:____871.5_____
 __Chlordane_____________:____0.488E-04________:__0.475E-03__:____872.5_____
 __Dieldrin______________:____0.326E-05________:__0.316E-04__:____870.5_____
 __Lead__________________:____0.271E-02________:__0.264E-01__:____872.9_____
 __Mercury_______________:____0.326E-02________:__0.316E-01__:____870.5_____
 __Nickel________________:____0.597E-04________:__0.580E-03__:____871.6_____
 __PCBs__________________:____0.832E-05________:__0.809E-04__:____871.8_____
 __Toxaphene_____________:____0.561E-04________:__0.545E-03__:____871.3_____
 __Vinyl Chloride________:____0.253E-02________:__0.246E-01__:____872.6_____
```

```
7/20/87          ALLOWABLE EMISSION RATES FOR POLLUTANTS        PAGE:  1
                 FROM SLUDGE INCINERATORS CALCULATED USING
                 THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
                              QUALITY CRITERIA
ILE USED: ISCTST4U.OUT
```

CASE 4

```
----------------------------------------------------------------------------------------------
                     ! ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES,
                     !          MICROGRAMS/M**3
                     !
                     !-------------------------------------------------------------------------
                     !  MAXIMUM     !     200m      !     500m      !      1000m
                     ! DISTANCE(a)  !_______________!_______________!______________________
                     !              !               !               !
                     !    3.90      !     3.90      !     2.06      !      1.00
                     !______________!_______________!_______________!______________________
                     !
 POLLUTANT NAME      !  ALLOWABLE EMISSION RATES, g/s
                     !
_____________________!_________________________________________________________________________
__Aldrin_____________!_0.113E-03___!_0.113E-03___!_0.213E-03__!_0.442E-03______
__Arsenic____________!_0.118E-03___!_0.118E-03___!_0.223E-03__!_0.462E-03______
__Benzo(A)pyrene_____!_0.292E-03___!_0.292E-03___!_0.553E-03__!_0.115E-02______
__Beryllium__________!_0.215E-03___!_0.215E-03___!_0.407E-03__!_0.844E-03______
__Bis(2 ethyl Hexyl)_!_0.127E+00___!_0.127E+00___!_0.240E+00__!_0.498E+00______
__Cadmium____________!_0.292E-03___!_0.292E-03___!_0.553E-03__!_0.115E-02______
__Carbon Tet.________!_0.138E-01___!_0.138E-01___!_0.262E-01__!_0.542E-01______
__Chromium +6________!_0.461E-04___!_0.461E-04___!_0.873E-04__!_0.181E-03______
__Chloroform_________!_0.220E-01___!_0.220E-01___!_0.417E-01__!_0.864E-01______
__Chlordane__________!_0.138E-02___!_0.138E-02___!_0.262E-02__!_0.542E-02______
__Dieldrin___________!_0.922E-04___!_0.922E-04___!_0.175E-03__!_0.362E-03______
__Lead_______________!_0.768E-01___!_0.768E-01___!_0.145E+00__!_0.301E+00______
__Mercury____________!_0.922E-01___!_0.922E-01___!_0.175E+00__!_0.362E+00______
__Nickel_____________!_0.169E-02___!_0.169E-02___!_0.320E-02__!_0.663E-02______
__PCBs_______________!_0.236E-03___!_0.236E-03___!_0.446E-03__!_0.924E-03______
__Toxaphene__________!_0.159E-02___!_0.159E-02___!_0.301E-02__!_0.623E-02______
__Vinyl Chloride_____!_0.717E-01___!_0.717E-01___!_0.136E+00__!_0.281E+00______

      (a) The maximum distance equals   200.000 meters.
```

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 4	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.113E-03	2731.7
Arsenic	0.416E-05	0.118E-03	2732.3
Benzo(A)pyrene	0.103E-04	0.292E-03	2735.0
Beryllium	0.760E-05	0.215E-03	2731.0
Bis(2 ethyl Hexyl)	0.449E-02	0.127E+00	2729.5
Cadmium	0.103E-04	0.292E-03	2735.0
Carbon Tet.	0.488E-03	0.138E-01	2734.3
Chromium +6	0.163E-05	0.461E-04	2728.6
Chloroform	0.778E-03	0.220E-01	2731.4
Chlordane	0.488E-04	0.138E-02	2734.3
Dieldrin	0.326E-05	0.922E-04	2728.6
Lead	0.271E-02	0.768E-01	2735.5
Mercury	0.326E-02	0.922E-01	2728.6
Nickel	0.597E-04	0.169E-02	2731.7
PCBs	0.832E-05	0.236E-03	2732.3
Toxaphene	0.561E-04	0.159E-02	2730.8
Vinyl Chloride	0.253E-02	0.717E-01	2734.8

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: ISCTST5U.OUT

CASE 5

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	68.84	19.20	5.36	1.77
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.639E-05	0.229E-04	0.820E-04	0.249E-03
Arsenic	0.668E-05	0.240E-04	0.858E-04	0.260E-03
Benzo(A)pyrene	0.166E-04	0.594E-04	0.213E-03	0.644E-03
Beryllium	0.122E-04	0.437E-04	0.157E-03	0.475E-03
Bis(2 ethyl Hexyl)	0.721E-02	0.258E-01	0.925E-01	0.280E+00
Cadmium	0.166E-04	0.594E-04	0.213E-03	0.644E-03
Carbon Tet.	0.784E-03	0.281E-02	0.101E-01	0.305E-01
Chromium +6	0.261E-05	0.937E-05	0.336E-04	0.102E-03
Chloroform	0.125E-02	0.448E-02	0.160E-01	0.486E-01
Chlordane	0.784E-04	0.281E-03	0.101E-02	0.305E-02
Dieldrin	0.523E-05	0.187E-04	0.671E-04	0.203E-03
Lead	0.436E-02	0.156E-01	0.559E-01	0.169E+00
Mercury	0.523E-02	0.187E-01	0.671E-01	0.203E+00
Nickel	0.959E-04	0.344E-03	0.123E-02	0.373E-02
PCBs	0.134E-04	0.479E-04	0.172E-03	0.520E-03
Toxaphene	0.901E-04	0.323E-03	0.116E-02	0.350E-02
Vinyl Chloride	0.407E-02	0.146E-01	0.522E-01	0.158E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM
GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 5	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.639E-05	60.6
Arsenic	0.416E-05	0.668E-05	60.6
Benzo(A)pyrene	0.103E-04	0.166E-04	60.8
Beryllium	0.760E-05	0.122E-04	60.6
Bis(2 ethyl Hexyl)	0.449E-02	0.721E-02	60.5
Cadmium	0.103E-04	0.166E-04	60.8
Carbon Tet.	0.488E-03	0.784E-03	60.7
Chromium +6	0.163E-05	0.261E-05	60.4
Chloroform	0.778E-03	0.125E-02	60.6
Chlordane	0.488E-04	0.784E-04	60.7
Dieldrin	0.326E-05	0.523E-05	60.4
Lead	0.271E-02	0.436E-02	60.8
Mercury	0.326E-02	0.523E-02	60.4
Nickel	0.597E-04	0.959E-04	60.6
PCBs	0.832E-05	0.134E-04	60.6
Toxaphene	0.561E-04	0.901E-04	60.5
Vinyl Chloride	0.253E-02	0.407E-02	60.8

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: ISCTST6U.OUT

Case 6

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	25.36	11.83	4.16	1.59
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.174E-04	0.372E-04	0.106E-03	0.277E-03
Arsenic	0.181E-04	0.389E-04	0.110E-03	0.289E-03
Benzo(A)pyrene	0.450E-04	0.964E-04	0.274E-03	0.717E-03
Beryllium	0.331E-04	0.710E-04	0.202E-03	0.528E-03
Bis(2 ethyl Hexyl)	0.196E-01	0.419E-01	0.119E+00	0.312E+00
Cadmium	0.450E-04	0.964E-04	0.274E-03	0.717E-03
Carbon Tet.	0.213E-02	0.457E-02	0.130E-01	0.340E-01
Chromium +6	0.710E-05	0.152E-04	0.432E-04	0.113E-03
Chloroform	0.339E-02	0.727E-02	0.207E-01	0.541E-01
Chlordane	0.213E-03	0.457E-03	0.130E-02	0.340E-02
Dieldrin	0.142E-04	0.304E-04	0.865E-04	0.226E-03
Lead	0.118E-01	0.254E-01	0.721E-01	0.189E+00
Mercury	0.142E-01	0.304E-01	0.865E-01	0.226E+00
Nickel	0.260E-03	0.558E-03	0.159E-02	0.415E-02
PCBs	0.363E-04	0.778E-04	0.221E-03	0.579E-03
Toxaphene	0.244E-03	0.524E-03	0.149E-02	0.390E-02
Vinyl Chloride	0.110E-01	0.237E-01	0.673E-01	0.176E+00

(a) The maximum distance equals 100.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 6	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.174E-04	335.9
Arsenic	0.416E-05	0.181E-04	336.0
Benzo(A)pyrene	0.103E-04	0.450E-04	336.4
Beryllium	0.760E-05	0.331E-04	335.8
Bis(2 ethyl Hexyl)	0.449E-02	0.196E-01	335.6
Cadmium	0.103E-04	0.450E-04	336.4
Carbon Tet.	0.488E-03	0.213E-02	336.3
Chromium +6	0.163E-05	0.710E-05	335.5
Chloroform	0.778E-03	0.339E-02	335.9
Chlordane	0.488E-04	0.213E-03	336.3
Dieldrin	0.326E-05	0.142E-04	335.5
Lead	0.271E-02	0.118E-01	336.5
Mercury	0.326E-02	0.142E-01	335.5
Nickel	0.597E-04	0.260E-03	335.9
PCBs	0.832E-05	0.363E-04	336.0
Toxaphene	0.561E-04	0.244E-03	335.8
Vinyl Chloride	0.253E-02	0.110E-01	336.4

```
07/20/87          ALLOWABLE EMISSION RATES FOR POLLUTANTS       PAGE:  1
                  FROM SLUDGE INCINERATORS CALCULATED USING
                  THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
                               QUALITY CRITERIA
FILE USED: \ISC\ISCLT\HART.OUT
```

CASE 7

```
-----------------------------------------------------------------------------
                       ! ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES,
                       !             MICROGRAMS/M**3
                       !
                       !-----------------------------------------------------
                       !  MAXIMUM   !    200m    !    500m    !    1000m
                       !_DISTANCE(a)_!____________!____________!______________
                       !            !            !            !
                       !   125.01   !    26.13   !     6.66   !     2.14
                       !____________!____________!____________!______________
                       !
  POLLUTANT NAME       !  ALLOWABLE EMISSION RATES, g/s
 ______________________!______________________________________________________
 _Aldrin_______________!_0.352E-05__!_0.168E-04__!_0.661E-04__!_0.205E-03_____
 __Arsenic_____________!_0.368E-05__!_0.176E-04__!_0.691E-04__!_0.215E-03_____
 _Benzo(A)pyrene_______!_0.912E-05__!_0.436E-04__!_0.171E-03__!_0.532E-03_____
 _Beryllium____________!_0.672E-05__!_0.322E-04__!_0.126E-03__!_0.392E-03_____
 __Bis(2 ethyl Hexyl)__!_0.397E-02__!_0.190E-01__!_0.745E-01__!_0.231E+00_____
 __Cadmium_____________!_0.912E-05__!_0.436E-04__!_0.171E-03__!_0.532E-03_____
 _Carbon Tet.__________!_0.432E-03__!_0.207E-02__!_0.811E-02__!_0.252E-01_____
 _Chromium +6__________!_0.144E-05__!_0.689E-05__!_0.270E-04__!_0.839E-04_____
 __Chloroform__________!_0.688E-03__!_0.329E-02__!_0.129E-01__!_0.401E-01_____
 _Chlordane____________!_0.432E-04__!_0.207E-03__!_0.811E-03__!_0.252E-02_____
 _Dieldrin_____________!_0.288E-05__!_0.138E-04__!_0.541E-04__!_0.168E-03_____
 __Lead________________!_0.240E-02__!_0.115E-01__!_0.451E-01__!_0.140E+00_____
 _Mercury______________!_0.288E-02__!_0.138E-01__!_0.541E-01__!_0.168E+00_____
 _Nickel_______________!_0.528E-04__!_0.253E-03__!_0.992E-03__!_0.308E-02_____
 _PCBs_________________!_0.736E-05__!_0.352E-04__!_0.138E-03__!_0.429E-03_____
 _Toxaphene____________!_0.496E-04__!_0.237E-03__!_0.932E-03__!_0.289E-02_____
 _Vinyl Chloride_______!_0.224E-02__!_0.107E-01__!_0.421E-01__!_0.131E+00_____

      (a) The maximum distance equals    50.000 meters.
```

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 7	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.352E-05	-11.6
Arsenic	0.416E-05	0.368E-05	-11.5
Benzo(A)pyrene	0.103E-04	0.912E-05	-11.5
Beryllium	0.760E-05	0.672E-05	-11.6
Bis(2 ethyl Hexyl)	0.449E-02	0.397E-02	-11.6
Cadmium	0.103E-04	0.912E-05	-11.5
Carbon Tet.	0.488E-03	0.432E-03	-11.5
Chromium +6	0.163E-05	0.144E-05	-11.7
Chloroform	0.778E-03	0.688E-03	-11.6
Chlordane	0.488E-04	0.432E-04	-11.5
Dieldrin	0.326E-05	0.288E-05	-11.7
Lead	0.271E-02	0.240E-02	-11.4
Mercury	0.326E-02	0.288E-02	-11.7
Nickel	0.597E-04	0.528E-04	-11.6
PCBs	0.832E-05	0.736E-05	-11.5
Toxaphene	0.561E-04	0.496E-04	-11.6
Vinyl Chloride	0.253E-02	0.224E-02	-11.5

```
07/20/87        ALLOWABLE EMISSION RATES FOR POLLUTANTS        PAGE:  1
                FROM SLUDGE INCINERATORS CALCULATED USING
                THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
                            QUALITY CRITERIA
FILE USED: \ISC\ISCLT\LOGAN.OUT
```

CASE 8

```
-------------------------------------------------------------------------------
                    ! ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES,
                    !          MICROGRAMS/M**3
                    !-----------------------------------------------------------
                    !  MAXIMUM    !    200m    !    500m    !     1000m
                    ! DISTANCE(a) !____________!____________!__________________
                    !             !            !            !
                    !    80.50    !   10.23    !    2.29    !     0.72
                    !_____________!____________!____________!__________________
                    !
 POLLUTANT NAME     !  ALLOWABLE EMISSION RATES, g/s
____________________!
 Aldrin             ! 0.547E-05   ! 0.430E-04  ! 0.192E-03  ! 0.613E-03
 Arsenic            ! 0.571E-05   ! 0.450E-04  ! 0.201E-03  ! 0.641E-03
 Benzo(A)pyrene     ! 0.142E-04   ! 0.111E-03  ! 0.498E-03  ! 0.159E-02
 Beryllium          ! 0.104E-04   ! 0.821E-04  ! 0.367E-03  ! 0.117E-02
 Bis(2 ethyl Hexyl) ! 0.616E-02   ! 0.485E-01  ! 0.217E+00  ! 0.691E+00
 Cadmium            ! 0.142E-04   ! 0.111E-03  ! 0.498E-03  ! 0.159E-02
 Carbon Tet.        ! 0.671E-03   ! 0.528E-02  ! 0.236E-01  ! 0.753E-01
 Chromium +6        ! 0.224E-05   ! 0.176E-04  ! 0.787E-04  ! 0.251E-03
 Chloroform         ! 0.107E-02   ! 0.841E-02  ! 0.376E-01  ! 0.120E+00
 Chlordane          ! 0.671E-04   ! 0.528E-03  ! 0.236E-02  ! 0.753E-02
 Dieldrin           ! 0.447E-05   ! 0.352E-04  ! 0.157E-03  ! 0.502E-03
 Lead               ! 0.373E-02   ! 0.293E-01  ! 0.131E+00  ! 0.418E+00
 Mercury            ! 0.447E-02   ! 0.352E-01  ! 0.157E+00  ! 0.502E+00
 Nickel             ! 0.820E-04   ! 0.645E-03  ! 0.289E-02  ! 0.920E-02
 PCBs               ! 0.114E-04   ! 0.899E-04  ! 0.402E-03  ! 0.128E-02
 Toxaphene          ! 0.770E-04   ! 0.606E-03  ! 0.271E-02  ! 0.864E-02
 Vinyl Chloride     ! 0.348E-02   ! 0.274E-01  ! 0.122E+00  ! 0.390E+00

      (a) The maximum distance equals    50.000 meters.
```

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 8	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.547E-05	37.3
Arsenic	0.416E-05	0.571E-05	37.4
Benzo(A)pyrene	0.103E-04	0.142E-04	37.5
Beryllium	0.760E-05	0.104E-04	37.3
Bis(2 ethyl Hexyl)	0.449E-02	0.616E-02	37.2
Cadmium	0.103E-04	0.142E-04	37.5
Carbon Tet.	0.488E-03	0.671E-03	37.5
Chromium +6	0.163E-05	0.224E-05	37.2
Chloroform	0.778E-03	0.107E-02	37.3
Chlordane	0.488E-04	0.671E-04	37.5
Dieldrin	0.326E-05	0.447E-05	37.2
Lead	0.271E-02	0.373E-02	37.5
Mercury	0.326E-02	0.447E-02	37.2
Nickel	0.597E-04	0.820E-04	37.3
PCBs	0.832E-05	0.114E-04	37.4
Toxaphene	0.561E-04	0.770E-04	37.3
Vinyl Chloride	0.253E-02	0.348E-02	37.5

```
07/20/87          ALLOWABLE EMISSION RATES FOR POLLUTANTS          PAGE:  1
                 FROM SLUDGE INCINERATORS CALCULATED USING
                 THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
                              QUALITY CRITERIA
FILE USED: \ISC\ISCLT\TETERNJ.OUT
```

CASE 9

```
-----------------------------------------------------------------------------------
                      ! ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES,
                      !            MICROGRAMS/M**3
                      !------------------------------------------------------------
                      !  MAXIMUM    !    200m     !    500m     !      1000m
                      ! DISTANCE(a) !             !             !
                      !             !             !             !
                      !   95.67     !   23.27     !    6.93     !      2.37
                      !             !             !             !
                      !
 POLLUTANT NAME       !  ALLOWABLE EMISSION RATES, g/s
                      !
 ---------------------!------------------------------------------------------------
 Aldrin               ! 0.460E-05   ! 0.189E-04   ! 0.635E-04   ! 0.185E-03
 Arsenic              ! 0.481E-05   ! 0.198E-04   ! 0.663E-04   ! 0.194E-03
 Benzo(A)pyrene       ! 0.119E-04   ! 0.490E-04   ! 0.164E-03   ! 0.480E-03
 Beryllium            ! 0.878E-05   ! 0.361E-04   ! 0.121E-03   ! 0.354E-03
 Bis(2 ethyl Hexyl)   ! 0.518E-02   ! 0.213E-01   ! 0.715E-01   ! 0.209E+00
 Cadmium              ! 0.119E-04   ! 0.490E-04   ! 0.164E-03   ! 0.480E-03
 Carbon Tet.          ! 0.564E-03   ! 0.232E-02   ! 0.779E-02   ! 0.228E-01
 Chromium +6          ! 0.188E-05   ! 0.773E-05   ! 0.260E-04   ! 0.758E-04
 Chloroform           ! 0.899E-03   ! 0.370E-02   ! 0.124E-01   ! 0.362E-01
 Chlordane            ! 0.564E-04   ! 0.232E-03   ! 0.779E-03   ! 0.228E-02
 Dieldrin             ! 0.376E-05   ! 0.155E-04   ! 0.519E-04   ! 0.152E-03
 Lead                 ! 0.314E-02   ! 0.129E-01   ! 0.433E-01   ! 0.126E+00
 Mercury              ! 0.376E-02   ! 0.155E-01   ! 0.519E-01   ! 0.152E+00
 Nickel               ! 0.690E-04   ! 0.284E-03   ! 0.952E-03   ! 0.278E-02
 PCBs                 ! 0.962E-05   ! 0.395E-04   ! 0.133E-03   ! 0.388E-03
 Toxaphene            ! 0.648E-04   ! 0.266E-03   ! 0.894E-03   ! 0.261E-02
 Vinyl Chloride       ! 0.293E-02   ! 0.120E-01   ! 0.404E-01   ! 0.118E+00

      (a) The maximum distance equals    50.000 meters.
```

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 9	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.460E-05	15.6
Arsenic	0.416E-05	0.481E-05	15.6
Benzo(A)pyrene	0.103E-04	0.119E-04	15.7
Beryllium	0.760E-05	0.878E-05	15.5
Bis(2 ethyl Hexyl)	0.449E-02	0.518E-02	15.5
Cadmium	0.103E-04	0.119E-04	15.7
Carbon Tet.	0.488E-03	0.564E-03	15.7
Chromium +6	0.163E-05	0.188E-05	15.4
Chloroform	0.778E-03	0.899E-03	15.5
Chlordane	0.488E-04	0.564E-04	15.7
Dieldrin	0.326E-05	0.376E-05	15.4
Lead	0.271E-02	0.314E-02	15.7
Mercury	0.326E-02	0.376E-02	15.4
Nickel	0.597E-04	0.690E-04	15.6
PCBs	0.832E-05	0.962E-05	15.6
Toxaphene	0.561E-04	0.648E-04	15.5
Vinyl Chloride	0.253E-02	0.293E-02	15.7

07/20/87 PAGE: 1

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: \ISC\ISCLT\PITTSBUR.OUT

CASE 10

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	106.77	19.14	4.70	1.49
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.412E-05	0.230E-04	0.936E-04	0.295E-03
Arsenic	0.431E-05	0.240E-04	0.978E-04	0.309E-03
Benzo(A)pyrene	0.107E-04	0.596E-04	0.242E-03	0.765E-03
Beryllium	0.787E-05	0.439E-04	0.179E-03	0.564E-03
Bis(2 ethyl Hexyl)	0.465E-02	0.259E-01	0.106E+00	0.333E+00
Cadmium	0.107E-04	0.596E-04	0.242E-03	0.765E-03
Carbon Tet.	0.506E-03	0.282E-02	0.115E-01	0.362E-01
Chromium +6	0.169E-05	0.940E-05	0.383E-04	0.121E-03
Chloroform	0.805E-03	0.449E-02	0.183E-01	0.577E-01
Chlordane	0.506E-04	0.282E-03	0.115E-02	0.362E-02
Dieldrin	0.337E-05	0.188E-04	0.766E-04	0.242E-03
Lead	0.281E-02	0.157E-01	0.638E-01	0.201E+00
Mercury	0.337E-02	0.188E-01	0.766E-01	0.242E+00
Nickel	0.618E-04	0.345E-03	0.140E-02	0.443E-02
PCBs	0.862E-05	0.481E-04	0.196E-03	0.617E-03
Toxaphene	0.581E-04	0.324E-03	0.132E-02	0.416E-02
Vinyl Chloride	0.262E-02	0.146E-01	0.596E-01	0.188E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 10	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.412E-05	3.5
Arsenic	0.416E-05	0.431E-05	3.6
Benzo(A)pyrene	0.103E-04	0.107E-04	3.7
Beryllium	0.760E-05	0.787E-05	3.5
Bis(2 ethyl Hexyl)	0.449E-02	0.465E-02	3.5
Cadmium	0.103E-04	0.107E-04	3.7
Carbon Tet.	0.488E-03	0.506E-03	3.6
Chromium +6	0.163E-05	0.169E-05	3.4
Chloroform	0.778E-03	0.805E-03	3.5
Chlordane	0.488E-04	0.506E-04	3.6
Dieldrin	0.326E-05	0.337E-05	3.4
Lead	0.271E-02	0.281E-02	3.7
Mercury	0.326E-02	0.337E-02	3.4
Nickel	0.597E-04	0.618E-04	3.5
PCBs	0.832E-05	0.862E-05	3.6
Toxaphene	0.561E-04	0.581E-04	3.5
Vinyl Chloride	0.253E-02	0.262E-02	3.7

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

PAGE: 1

FILE USED: \ISC\ISCLT\SAV.OUT

CASE 11

POLLUTANT NAME	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	92.01	18.75	5.27	1.77
	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.478E-05	0.235E-04	0.834E-04	0.249E-03
Arsenic	0.500E-05	0.245E-04	0.872E-04	0.260E-03
Benzo(A)pyrene	0.124E-04	0.608E-04	0.216E-03	0.644E-03
Beryllium	0.913E-05	0.448E-04	0.159E-03	0.474E-03
Bis(2 ethyl Hexyl)	0.539E-02	0.265E-01	0.941E-01	0.280E+00
Cadmium	0.124E-04	0.608E-04	0.216E-03	0.644E-03
Carbon Tet.	0.587E-03	0.288E-02	0.102E-01	0.305E-01
Chromium +6	0.196E-05	0.960E-05	0.341E-04	0.102E-03
Chloroform	0.935E-03	0.459E-02	0.163E-01	0.486E-01
Chlordane	0.587E-04	0.288E-03	0.102E-02	0.305E-02
Dieldrin	0.391E-05	0.192E-04	0.683E-04	0.203E-03
Lead	0.326E-02	0.160E-01	0.569E-01	0.169E+00
Mercury	0.391E-02	0.192E-01	0.683E-01	0.203E+00
Nickel	0.717E-04	0.352E-03	0.125E-02	0.373E-02
PCBs	0.100E-04	0.491E-04	0.174E-03	0.520E-03
Toxaphene	0.674E-04	0.331E-03	0.118E-02	0.350E-02
Vinyl Chloride	0.304E-02	0.149E-01	0.531E-01	0.158E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 11	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.478E-05	20.2
Arsenic	0.416E-05	0.500E-05	20.2
Benzo(A)pyrene	0.103E-04	0.124E-04	20.3
Beryllium	0.760E-05	0.913E-05	20.1
Bis(2 ethyl Hexyl)	0.449E-02	0.539E-02	20.1
Cadmium	0.103E-04	0.124E-04	20.3
Carbon Tet.	0.488E-03	0.587E-03	20.3
Chromium +6	0.163E-05	0.196E-05	20.0
Chloroform	0.778E-03	0.935E-03	20.1
Chlordane	0.488E-04	0.587E-04	20.3
Dieldrin	0.326E-05	0.391E-05	20.0
Lead	0.271E-02	0.326E-02	20.3
Mercury	0.326E-02	0.391E-02	20.0
Nickel	0.597E-04	0.717E-04	20.2
PCBs	0.832E-05	0.100E-04	20.2
Toxaphene	0.561E-04	0.674E-04	20.1
Vinyl Chloride	0.253E-02	0.304E-02	20.3

```
7/20/87           ALLOWABLE EMISSION RATES FOR POLLUTANTS          PAGE:  1
                  FROM SLUDGE INCINERATORS CALCULATED USING
                  THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
                               QUALITY CRITERIA
ILE USED: \ISC\ISCLT\ANNIS.OUT
```

CASE 12

```
-----------------------------------------------------------------------------------
                     : ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES,
                     :           MICROGRAMS/M**3
                     :
                     :------------------------------------------------------------
                     :   MAXIMUM    :    200m     :     500m     :     1000m
                     :_DISTANCE(a)_ :_____________:______________:_________________
                     :              :             :              :
                     :   129.23     :    35.99    :    10.47     :     3.57
                     :______________:_____________:______________:_________________
                     :
 POLLUTANT NAME      :  ALLOWABLE EMISSION RATES, g/s
_____________________:____________________________________________________________
__Aldrin_____________:_0.340E-05___:_0.122E-04__:_0.420E-04__:_0.123E-03_______
__Arsenic____________:_0.356E-05___:_0.128E-04__:_0.439E-04__:_0.129E-03_______
__Benzo(A)pyrene_____:_0.882E-05___:_0.317E-04__:_0.109E-03__:_0.320E-03_______
__Beryllium__________:_0.650E-05___:_0.233E-04__:_0.802E-04__:_0.235E-03_______
__Bis(2_ethyl_Hexyl)_:_0.384E-02___:_0.138E-01__:_0.474E-01__:_0.139E+00_______
__Cadmium____________:_0.882E-05___:_0.317E-04__:_0.109E-03__:_0.320E-03_______
__Carbon_Tet.________:_0.418E-03___:_0.150E-02__:_0.516E-02__:_0.151E-01_______
__Chromium_+6________:_0.139E-05___:_0.500E-05__:_0.172E-04__:_0.504E-04_______
__Chloroform_________:_0.665E-03___:_0.239E-02__:_0.821E-02__:_0.241E-01_______
__Chlordane__________:_0.418E-04___:_0.150E-03__:_0.516E-03__:_0.151E-02_______
__Dieldrin___________:_0.279E-05___:_0.100E-04__:_0.344E-04__:_0.101E-03_______
__Lead_______________:_0.232E-02___:_0.834E-02__:_0.287E-01__:_0.841E-01_______
__Mercury____________:_0.279E-02___:_0.100E-01__:_0.344E-01__:_0.101E+00_______
__Nickel_____________:_0.511E-04___:_0.183E-03__:_0.630E-03__:_0.185E-02_______
__PCBs_______________:_0.712E-05___:_0.256E-04__:_0.879E-04__:_0.258E-03_______
__Toxaphene__________:_0.480E-04___:_0.172E-03__:_0.592E-03__:_0.174E-02_______
__Vinyl_Chloride_____:_0.217E-02___:_0.778E-02__:_0.267E-01__:_0.785E-01_______

      (a) The maximum distance equals    50.000 meters.
```

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 12	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.340E-05	-14.5
Arsenic	0.416E-05	0.356E-05	-14.4
Benzo(A)pyrene	0.103E-04	0.882E-05	-14.4
Beryllium	0.760E-05	0.650E-05	-14.5
Bis(2 ethyl Hexyl)	0.449E-02	0.384E-02	-14.5
Cadmium	0.103E-04	0.882E-05	-14.4
Carbon Tet.	0.488E-03	0.418E-03	-14.4
Chromium +6	0.163E-05	0.139E-05	-14.6
Chloroform	0.778E-03	0.665E-03	-14.5
Chlordane	0.488E-04	0.418E-04	-14.4
Dieldrin	0.326E-05	0.279E-05	-14.6
Lead	0.271E-02	0.232E-02	-14.3
Mercury	0.326E-02	0.279E-02	-14.6
Nickel	0.597E-04	0.511E-04	-14.5
PCBs	0.832E-05	0.712E-05	-14.4
Toxaphene	0.561E-04	0.480E-04	-14.5
Vinyl Chloride	0.253E-02	0.217E-02	-14.4

```
7/20/87          ALLOWABLE EMISSION RATES FOR POLLUTANTS        PAGE:  1
                FROM SLUDGE INCINERATORS CALCULATED USING
                THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
                             QUALITY CRITERIA
ILE USED: \ISC\ISCLT\DAYTON.OUT
```

Case 13

```
-----------------------------------------------------------------------------------
                     | ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES,
                     |           MICROGRAMS/M**3
                     |
                     |-------------------------------------------------------------
                     |  MAXIMUM    |    200m     |    500m     |     1000m
                     | DISTANCE(a) |_____________|_____________|______________________
                     |             |             |             |
                     |    99.60    |    17.44    |     4.38    |     1.41
                     |_____________|_____________|_____________|______________________
                     |
 POLLUTANT NAME      |  ALLOWABLE EMISSION RATES, g/s
_____________________|_____________________________________________________________
__Aldrin_____________|_0.442E-05___|_0.252E-04__|_0.100E-03__|_0.312E-03_______
_Arsenic_____________|_0.462E-05___|_0.264E-04__|_0.105E-03__|_0.326E-03_______
_Benzo(A)pyrene______|_0.114E-04___|_0.654E-04__|_0.260E-03__|_0.807E-03_______
__Beryllium__________|_0.843E-05___|_0.482E-04__|_0.192E-03__|_0.595E-03_______
_Bis(2_ethyl_Hexyl)__|_0.498E-02___|_0.284E-01__|_0.113E+00__|_0.351E+00_______
_Cadmium_____________|_0.114E-04___|_0.654E-04__|_0.260E-03__|_0.807E-03_______
__Carbon_Tet.________|_0.542E-03___|_0.310E-02__|_0.123E-01__|_0.382E-01_______
__Chromium_+6________|_0.181E-05___|_0.103E-04__|_0.411E-04__|_0.127E-03_______
_Chloroform__________|_0.863E-03___|_0.493E-02__|_0.196E-01__|_0.609E-01_______
_Chlordane___________|_0.542E-04___|_0.310E-03__|_0.123E-02__|_0.382E-02_______
__Dieldrin___________|_0.361E-05___|_0.206E-04__|_0.822E-04__|_0.255E-03_______
_Lead________________|_0.301E-02___|_0.172E-01__|_0.685E-01__|_0.212E+00_______
_Mercury_____________|_0.361E-02___|_0.206E-01__|_0.822E-01__|_0.255E+00_______
__Nickel_____________|_0.663E-04___|_0.378E-03__|_0.151E-02__|_0.467E-02_______
_PCBs________________|_0.924E-05___|_0.527E-04__|_0.210E-03__|_0.651E-03_______
_Toxaphene___________|_0.623E-04___|_0.355E-03__|_0.141E-02__|_0.439E-02_______
__Vinyl_Chloride_____|_0.281E-02___|_0.161E-01__|_0.639E-01__|_0.198E+00_______

      (a) The maximum distance equals    50.000 meters.
```

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 13	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.442E-05	11.0
Arsenic	0.416E-05	0.462E-05	11.0
Benzo(A)pyrene	0.103E-04	0.114E-04	11.1
Beryllium	0.760E-05	0.843E-05	11.0
Bis(2 ethyl Hexyl)	0.449E-02	0.498E-02	10.9
Cadmium	0.103E-04	0.114E-04	11.1
Carbon Tet.	0.488E-03	0.542E-03	11.1
Chromium +6	0.163E-05	0.181E-05	10.9
Chloroform	0.778E-03	0.863E-03	11.0
Chlordane	0.488E-04	0.542E-04	11.1
Dieldrin	0.326E-05	0.361E-05	10.9
Lead	0.271E-02	0.301E-02	11.1
Mercury	0.326E-02	0.361E-02	10.9
Nickel	0.597E-04	0.663E-04	11.0
PCBs	0.832E-05	0.924E-05	11.0
Toxaphene	0.561E-04	0.623E-04	11.0
Vinyl Chloride	0.253E-02	0.281E-02	11.1

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

PAGE: 1

FILE USED: \ISC\ISCLT\HOUSTON.OUT

CASE 14

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	88.05	20.30	5.59	1.85
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.500E-05	0.217E-04	0.787E-04	0.238E-03
Arsenic	0.522E-05	0.227E-04	0.823E-04	0.248E-03
Benzo(A)pyrene	0.129E-04	0.562E-04	0.204E-03	0.615E-03
Beryllium	0.954E-05	0.414E-04	0.150E-03	0.454E-03
Bis(2 ethyl Hexyl)	0.563E-02	0.244E-01	0.887E-01	0.268E+00
Cadmium	0.129E-04	0.562E-04	0.204E-03	0.615E-03
Carbon Tet.	0.613E-03	0.266E-02	0.966E-02	0.292E-01
Chromium +6	0.204E-05	0.887E-05	0.322E-04	0.972E-04
Chloroform	0.977E-03	0.424E-02	0.154E-01	0.464E-01
Chlordane	0.613E-04	0.266E-03	0.966E-03	0.292E-02
Dieldrin	0.409E-05	0.177E-04	0.644E-04	0.194E-03
Lead	0.341E-02	0.148E-01	0.537E-01	0.162E+00
Mercury	0.409E-02	0.177E-01	0.644E-01	0.194E+00
Nickel	0.750E-04	0.325E-03	0.118E-02	0.356E-02
PCBs	0.104E-04	0.453E-04	0.165E-03	0.497E-03
Toxaphene	0.704E-04	0.305E-03	0.111E-02	0.335E-02
Vinyl Chloride	0.318E-02	0.138E-01	0.501E-01	0.151E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 14	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.500E-05	25.6
Arsenic	0.416E-05	0.522E-05	25.6
Benzo(A)pyrene	0.103E-04	0.129E-04	25.7
Beryllium	0.760E-05	0.954E-05	25.5
Bis(2 ethyl Hexyl)	0.449E-02	0.563E-02	25.5
Cadmium	0.103E-04	0.129E-04	25.7
Carbon Tet.	0.488E-03	0.613E-03	25.7
Chromium +6	0.163E-05	0.204E-05	25.4
Chloroform	0.778E-03	0.977E-03	25.5
Chlordane	0.488E-04	0.613E-04	25.7
Dieldrin	0.326E-05	0.409E-05	25.4
Lead	0.271E-02	0.341E-02	25.7
Mercury	0.326E-02	0.409E-02	25.4
Nickel	0.597E-04	0.750E-04	25.6
PCBs	0.832E-05	0.104E-04	25.6
Toxaphene	0.561E-04	0.704E-04	25.5
Vinyl Chloride	0.253E-02	0.318E-02	25.7

07/20/87 PAGE: 1

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: \ISC\ISCLT\DALLAS.OUT

CASE 15

POLLUTANT NAME	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	148.57	22.84	5.44	1.72
	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.296E-05	0.193E-04	0.810E-04	0.255E-03
Arsenic	0.310E-05	0.201E-04	0.846E-04	0.267E-03
Benzo(A)pyrene	0.767E-05	0.499E-04	0.210E-03	0.662E-03
Beryllium	0.565E-05	0.368E-04	0.155E-03	0.488E-03
Bis(2 ethyl Hexyl)	0.334E-02	0.217E-01	0.913E-01	0.288E+00
Cadmium	0.767E-05	0.499E-04	0.210E-03	0.662E-03
Carbon Tet.	0.363E-03	0.236E-02	0.994E-02	0.313E-01
Chromium +6	0.121E-05	0.788E-05	0.331E-04	0.104E-03
Chloroform	0.579E-03	0.377E-02	0.158E-01	0.499E-01
Chlordane	0.363E-04	0.236E-03	0.994E-03	0.313E-02
Dieldrin	0.242E-05	0.158E-04	0.662E-04	0.209E-03
Lead	0.202E-02	0.131E-01	0.552E-01	0.174E+00
Mercury	0.242E-02	0.158E-01	0.662E-01	0.209E+00
Nickel	0.444E-04	0.289E-03	0.121E-02	0.383E-02
PCBs	0.619E-05	0.403E-04	0.169E-03	0.534E-03
Toxaphene	0.417E-04	0.271E-03	0.114E-02	0.360E-02
Vinyl Chloride	0.188E-02	0.123E-01	0.515E-01	0.163E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 15	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.296E-05	-25.6
Arsenic	0.416E-05	0.310E-05	-25.6
Benzo(A)pyrene	0.103E-04	0.767E-05	-25.5
Beryllium	0.760E-05	0.565E-05	-25.6
Bis(2 ethyl Hexyl)	0.449E-02	0.334E-02	-25.6
Cadmium	0.103E-04	0.767E-05	-25.5
Carbon Tet.	0.488E-03	0.363E-03	-25.5
Chromium +6	0.163E-05	0.121E-05	-25.7
Chloroform	0.778E-03	0.579E-03	-25.6
Chlordane	0.488E-04	0.363E-04	-25.5
Dieldrin	0.326E-05	0.242E-05	-25.7
Lead	0.271E-02	0.202E-02	-25.5
Mercury	0.326E-02	0.242E-02	-25.7
Nickel	0.597E-04	0.444E-04	-25.6
PCBs	0.832E-05	0.619E-05	-25.6
Toxaphene	0.561E-04	0.417E-04	-25.6
Vinyl Chloride	0.253E-02	0.188E-02	-25.5

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

PAGE: 1

FILE USED: \ISC\ISCLT\SANTAFE.OUT

CASE 16

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	90.30	17.15	4.42	1.46
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.487E-05	0.257E-04	0.995E-04	0.302E-03
Arsenic	0.509E-05	0.268E-04	0.104E-03	0.316E-03
Benzo(A)pyrene	0.126E-04	0.665E-04	0.258E-03	0.782E-03
Beryllium	0.930E-05	0.490E-04	0.190E-03	0.576E-03
Bis(2 ethyl Hexyl)	0.549E-02	0.289E-01	0.112E+00	0.340E+00
Cadmium	0.126E-04	0.665E-04	0.258E-03	0.782E-03
Carbon Tet.	0.598E-03	0.315E-02	0.122E-01	0.370E-01
Chromium +6	0.199E-05	0.105E-04	0.407E-04	0.123E-03
Chloroform	0.952E-03	0.502E-02	0.195E-01	0.590E-01
Chlordane	0.598E-04	0.315E-03	0.122E-02	0.370E-02
Dieldrin	0.399E-05	0.210E-04	0.814E-04	0.247E-03
Lead	0.332E-02	0.175E-01	0.679E-01	0.206E+00
Mercury	0.399E-02	0.210E-01	0.814E-01	0.247E+00
Nickel	0.731E-04	0.385E-03	0.149E-02	0.453E-02
PCBs	0.102E-04	0.537E-04	0.208E-03	0.631E-03
Toxaphene	0.687E-04	0.362E-03	0.140E-02	0.425E-02
Vinyl Chloride	0.310E-02	0.163E-01	0.633E-01	0.192E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 16	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.487E-05	22.4
Arsenic	0.416E-05	0.509E-05	22.5
Benzo(A)pyrene	0.103E-04	0.126E-04	22.6
Beryllium	0.760E-05	0.930E-05	22.4
Bis(2 ethyl Hexyl)	0.449E-02	0.549E-02	22.3
Cadmium	0.103E-04	0.126E-04	22.6
Carbon Tet.	0.488E-03	0.598E-03	22.5
Chromium +6	0.163E-05	0.199E-05	22.3
Chloroform	0.778E-03	0.952E-03	22.4
Chlordane	0.488E-04	0.598E-04	22.5
Dieldrin	0.326E-05	0.399E-05	22.3
Lead	0.271E-02	0.332E-02	22.6
Mercury	0.326E-02	0.399E-02	22.3
Nickel	0.597E-04	0.731E-04	22.4
PCBs	0.832E-05	0.102E-04	22.5
Toxaphene	0.561E-04	0.687E-04	22.4
Vinyl Chloride	0.253E-02	0.310E-02	22.6

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: \ISC\ISCLT\TOPEKA.OUT

CASE 17

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	128.04	22.93	5.68	1.81
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.344E-05	0.192E-04	0.775E-04	0.243E-03
Arsenic	0.359E-05	0.201E-04	0.810E-04	0.254E-03
Benzo(A)pyrene	0.890E-05	0.497E-04	0.201E-03	0.629E-03
Beryllium	0.656E-05	0.366E-04	0.148E-03	0.463E-03
Bis(2 ethyl Hexyl)	0.387E-02	0.216E-01	0.873E-01	0.274E+00
Cadmium	0.890E-05	0.497E-04	0.201E-03	0.629E-03
Carbon Tet.	0.422E-03	0.236E-02	0.951E-02	0.298E-01
Chromium +6	0.141E-05	0.785E-05	0.317E-04	0.993E-04
Chloroform	0.672E-03	0.375E-02	0.151E-01	0.474E-01
Chlordane	0.422E-04	0.236E-03	0.951E-03	0.298E-02
Dieldrin	0.281E-05	0.157E-04	0.634E-04	0.199E-03
Lead	0.234E-02	0.131E-01	0.528E-01	0.165E+00
Mercury	0.281E-02	0.157E-01	0.634E-01	0.199E+00
Nickel	0.515E-04	0.288E-03	0.116E-02	0.364E-02
PCBs	0.719E-05	0.401E-04	0.162E-03	0.507E-03
Toxaphene	0.484E-04	0.270E-03	0.109E-02	0.342E-02
Vinyl Chloride	0.219E-02	0.122E-01	0.493E-01	0.154E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 17	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.344E-05	-13.7
Arsenic	0.416E-05	0.359E-05	-13.6
Benzo(A)pyrene	0.103E-04	0.890E-05	-13.6
Beryllium	0.760E-05	0.656E-05	-13.7
Bis(2 ethyl Hexyl)	0.449E-02	0.387E-02	-13.7
Cadmium	0.103E-04	0.890E-05	-13.6
Carbon Tet.	0.488E-03	0.422E-03	-13.6
Chromium +6	0.163E-05	0.141E-05	-13.8
Chloroform	0.778E-03	0.672E-03	-13.7
Chlordane	0.488E-04	0.422E-04	-13.6
Dieldrin	0.326E-05	0.281E-05	-13.8
Lead	0.271E-02	0.234E-02	-13.5
Mercury	0.326E-02	0.281E-02	-13.8
Nickel	0.597E-04	0.515E-04	-13.7
PCBs	0.832E-05	0.719E-05	-13.6
Toxaphene	0.561E-04	0.484E-04	-13.7
Vinyl Chloride	0.253E-02	0.219E-02	-13.6

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

PAGE: 1

FILE USED: \ISC\ISCLT\DETROIT.OUT

CASE 18

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	103.04	16.86	4.11	1.31
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.427E-05	0.261E-04	0.107E-03	0.336E-03
Arsenic	0.446E-05	0.273E-04	0.112E-03	0.352E-03
Benzo(A)pyrene	0.111E-04	0.676E-04	0.278E-03	0.871E-03
Beryllium	0.815E-05	0.498E-04	0.204E-03	0.642E-03
Bis(2 ethyl Hexyl)	0.481E-02	0.294E-01	0.121E+00	0.379E+00
Cadmium	0.111E-04	0.676E-04	0.278E-03	0.871E-03
Carbon Tet.	0.524E-03	0.320E-02	0.131E-01	0.413E-01
Chromium +6	0.175E-05	0.107E-04	0.438E-04	0.138E-03
Chloroform	0.835E-03	0.510E-02	0.209E-01	0.657E-01
Chlordane	0.524E-04	0.320E-03	0.131E-02	0.413E-02
Dieldrin	0.349E-05	0.213E-04	0.876E-04	0.275E-03
Lead	0.291E-02	0.178E-01	0.730E-01	0.229E+00
Mercury	0.349E-02	0.213E-01	0.876E-01	0.275E+00
Nickel	0.641E-04	0.391E-03	0.161E-02	0.504E-02
PCBs	0.893E-05	0.546E-04	0.224E-03	0.703E-03
Toxaphene	0.602E-04	0.368E-03	0.151E-02	0.474E-02
Vinyl Chloride	0.272E-02	0.166E-01	0.682E-01	0.214E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 18	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.427E-05	7.3
Arsenic	0.416E-05	0.446E-05	7.3
Benzo(A)pyrene	0.103E-04	0.111E-04	7.4
Beryllium	0.760E-05	0.815E-05	7.3
Bis(2 ethyl Hexyl)	0.449E-02	0.481E-02	7.2
Cadmium	0.103E-04	0.111E-04	7.4
Carbon Tet.	0.488E-03	0.524E-03	7.4
Chromium +6	0.163E-05	0.175E-05	7.2
Chloroform	0.778E-03	0.835E-03	7.3
Chlordane	0.488E-04	0.524E-04	7.4
Dieldrin	0.326E-05	0.349E-05	7.2
Lead	0.271E-02	0.291E-02	7.4
Mercury	0.326E-02	0.349E-02	7.2
Nickel	0.597E-04	0.641E-04	7.3
PCBs	0.832E-05	0.893E-05	7.3
Toxaphene	0.561E-04	0.602E-04	7.3
Vinyl Chloride	0.253E-02	0.272E-02	7.4

07/20/87 ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA PAGE: 1

FILE USED: \ISC\ISCLT\SANJUAN.OUT

CASE 19

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	185.37	32.57	9.62	3.28
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.237E-05	0.135E-04	0.457E-04	0.134E-03
Arsenic	0.248E-05	0.141E-04	0.478E-04	0.140E-03
Benzo(A)pyrene	0.615E-05	0.350E-04	0.118E-03	0.347E-03
Beryllium	0.453E-05	0.258E-04	0.873E-04	0.256E-03
Bis(2 ethyl Hexyl)	0.268E-02	0.152E-01	0.515E-01	0.151E+00
Cadmium	0.615E-05	0.350E-04	0.118E-03	0.347E-03
Carbon Tet.	0.291E-03	0.166E-02	0.561E-02	0.165E-01
Chromium +6	0.971E-06	0.553E-05	0.187E-04	0.548E-04
Chloroform	0.464E-03	0.264E-02	0.894E-02	0.262E-01
Chlordane	0.291E-04	0.166E-03	0.561E-03	0.165E-02
Dieldrin	0.194E-05	0.111E-04	0.374E-04	0.110E-03
Lead	0.162E-02	0.921E-02	0.312E-01	0.914E-01
Mercury	0.194E-02	0.111E-01	0.374E-01	0.110E+00
Nickel	0.356E-04	0.203E-03	0.686E-03	0.201E-02
PCBs	0.496E-05	0.282E-04	0.956E-04	0.280E-03
Toxaphene	0.334E-04	0.190E-03	0.644E-03	0.189E-02
Vinyl Chloride	0.151E-02	0.860E-02	0.291E-01	0.853E-01

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 19	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.237E-05	-40.4
Arsenic	0.416E-05	0.248E-05	-40.3
Benzo(A)pyrene	0.103E-04	0.615E-05	-40.3
Beryllium	0.760E-05	0.453E-05	-40.4
Bis(2 ethyl Hexyl)	0.449E-02	0.268E-02	-40.4
Cadmium	0.103E-04	0.615E-05	-40.3
Carbon Tet.	0.488E-03	0.291E-03	-40.3
Chromium +6	0.163E-05	0.971E-06	-40.4
Chloroform	0.778E-03	0.464E-03	-40.4
Chlordane	0.488E-04	0.291E-04	-40.3
Dieldrin	0.326E-05	0.194E-05	-40.4
Lead	0.271E-02	0.162E-02	-40.3
Mercury	0.326E-02	0.194E-02	-40.4
Nickel	0.597E-04	0.356E-04	-40.4
PCBs	0.832E-05	0.496E-05	-40.3
Toxaphene	0.561E-04	0.334E-04	-40.4
Vinyl Chloride	0.253E-02	0.151E-02	-40.3

C- A.4D

ALLOWABLE EMISSION RATES FOR POLLUTANTS
FROM SLUDGE INCINERATORS CALCULATED USING
THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
QUALITY CRITERIA

FILE USED: \ISC\ISCLT\MILES.OUT

Case 20

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	90.53	18.08	4.64	1.53
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.486E-05	0.243E-04	0.949E-04	0.289E-03
Arsenic	0.508E-05	0.254E-04	0.992E-04	0.302E-03
Benzo(A)pyrene	0.126E-04	0.631E-04	0.246E-03	0.747E-03
Beryllium	0.928E-05	0.465E-04	0.181E-03	0.551E-03
Bis(2 ethyl Hexyl)	0.548E-02	0.274E-01	0.107E+00	0.325E+00
Cadmium	0.126E-04	0.631E-04	0.246E-03	0.747E-03
Carbon Tet.	0.596E-03	0.299E-02	0.116E-01	0.354E-01
Chromium +6	0.199E-05	0.996E-05	0.388E-04	0.118E-03
Chloroform	0.950E-03	0.476E-02	0.186E-01	0.564E-01
Chlordane	0.596E-04	0.299E-03	0.116E-02	0.354E-02
Dieldrin	0.398E-05	0.199E-04	0.777E-04	0.236E-03
Lead	0.331E-02	0.166E-01	0.647E-01	0.197E+00
Mercury	0.398E-02	0.199E-01	0.777E-01	0.236E+00
Nickel	0.729E-04	0.365E-03	0.142E-02	0.433E-02
PCBs	0.102E-04	0.509E-04	0.198E-03	0.603E-03
Toxaphene	0.685E-04	0.343E-03	0.134E-02	0.407E-02
Vinyl Chloride	0.309E-02	0.155E-01	0.604E-01	0.184E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 20	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.486E-05	22.1
Arsenic	0.416E-05	0.508E-05	22.1
Benzo(A)pyrene	0.103E-04	0.126E-04	22.3
Beryllium	0.760E-05	0.928E-05	22.1
Bis(2 ethyl Hexyl)	0.449E-02	0.548E-02	22.0
Cadmium	0.103E-04	0.126E-04	22.3
Carbon Tet.	0.488E-03	0.596E-03	22.2
Chromium +6	0.163E-05	0.199E-05	22.0
Chloroform	0.778E-03	0.950E-03	22.1
Chlordane	0.488E-04	0.596E-04	22.2
Dieldrin	0.326E-05	0.398E-05	22.0
Lead	0.271E-02	0.331E-02	22.3
Mercury	0.326E-02	0.398E-02	22.0
Nickel	0.597E-04	0.729E-04	22.1
PCBs	0.832E-05	0.102E-04	22.1
Toxaphene	0.561E-04	0.685E-04	22.1
Vinyl Chloride	0.253E-02	0.309E-02	22.2

ALLOWABLE EMISSION RATES FOR POLLUTANTS
FROM SLUDGE INCINERATORS CALCULATED USING
THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
QUALITY CRITERIA

FILE USED: \ISC\ISCLT\DENVER.OUT

CASE 21

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	131.81	30.16	8.93	3.10
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.334E-05	0.146E-04	0.493E-04	0.142E-03
Arsenic	0.349E-05	0.153E-04	0.515E-04	0.148E-03
Benzo(A)pyrene	0.865E-05	0.378E-04	0.128E-03	0.368E-03
Beryllium	0.637E-05	0.279E-04	0.940E-04	0.271E-03
Bis(2 ethyl Hexyl)	0.376E-02	0.164E-01	0.555E-01	0.160E+00
Cadmium	0.865E-05	0.378E-04	0.128E-03	0.368E-03
Carbon Tet.	0.410E-03	0.179E-02	0.605E-02	0.174E-01
Chromium +6	0.137E-05	0.597E-05	0.202E-04	0.581E-04
Chloroform	0.652E-03	0.285E-02	0.963E-02	0.277E-01
Chlordane	0.410E-04	0.179E-03	0.605E-03	0.174E-02
Dieldrin	0.273E-05	0.119E-04	0.403E-04	0.116E-03
Lead	0.228E-02	0.995E-02	0.336E-01	0.968E-01
Mercury	0.273E-02	0.119E-01	0.403E-01	0.116E+00
Nickel	0.501E-04	0.219E-03	0.739E-03	0.213E-02
PCBs	0.698E-05	0.305E-04	0.103E-03	0.297E-03
Toxaphene	0.470E-04	0.206E-03	0.694E-03	0.200E-02
Vinyl Chloride	0.212E-02	0.929E-02	0.313E-01	0.903E-01

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM
GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 21	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.334E-05	-16.1
Arsenic	0.416E-05	0.349E-05	-16.1
Benzo(A)pyrene	0.103E-04	0.865E-05	-16.0
Beryllium	0.760E-05	0.637E-05	-16.1
Bis(2 ethyl Hexyl)	0.449E-02	0.376E-02	-16.2
Cadmium	0.103E-04	0.865E-05	-16.0
Carbon Tet.	0.488E-03	0.410E-03	-16.1
Chromium +6	0.163E-05	0.137E-05	-16.2
Chloroform	0.778E-03	0.652E-03	-16.1
Chlordane	0.488E-04	0.410E-04	-16.1
Dieldrin	0.326E-05	0.273E-05	-16.2
Lead	0.271E-02	0.228E-02	-16.0
Mercury	0.326E-02	0.273E-02	-16.2
Nickel	0.597E-04	0.501E-04	-16.1
PCBs	0.832E-05	0.698E-05	-16.1
Toxaphene	0.561E-04	0.470E-04	-16.2
Vinyl Chloride	0.253E-02	0.212E-02	-16.0

07/20/87 ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA PAGE: 1

FILE USED: \ISC\ISCLT\LA.OUT

Case 22

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES. MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	190.64	32.85	7.86	2.47
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.231E-05	0.134E-04	0.559E-04	0.178E-03
Arsenic	0.241E-05	0.140E-04	0.585E-04	0.187E-03
Benzo(A)pyrene	0.598E-05	0.347E-04	0.145E-03	0.462E-03
Beryllium	0.441E-05	0.256E-04	0.107E-03	0.341E-03
Bis(2 ethyl Hexyl)	0.260E-02	0.151E-01	0.631E-01	0.201E+00
Cadmium	0.598E-05	0.347E-04	0.145E-03	0.462E-03
Carbon Tet.	0.283E-03	0.164E-02	0.687E-02	0.219E-01
Chromium +6	0.944E-06	0.548E-05	0.229E-04	0.730E-04
Chloroform	0.451E-03	0.262E-02	0.109E-01	0.349E-01
Chlordane	0.283E-04	0.164E-03	0.687E-03	0.219E-02
Dieldrin	0.189E-05	0.110E-04	0.458E-04	0.146E-03
Lead	0.157E-02	0.913E-02	0.381E-01	0.122E+00
Mercury	0.189E-02	0.110E-01	0.458E-01	0.146E+00
Nickel	0.346E-04	0.201E-03	0.839E-03	0.268E-02
PCBs	0.483E-05	0.280E-04	0.117E-03	0.373E-03
Toxaphene	0.325E-04	0.189E-03	0.788E-03	0.251E-02
Vinyl Chloride	0.147E-02	0.852E-02	0.356E-01	0.114E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM
GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 22	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.231E-05	-42.0
Arsenic	0.416E-05	0.241E-05	-42.0
Benzo(A)pyrene	0.103E-04	0.598E-05	-41.9
Beryllium	0.760E-05	0.441E-05	-42.0
Bis(2 ethyl Hexyl)	0.449E-02	0.260E-02	-42.1
Cadmium	0.103E-04	0.598E-05	-41.9
Carbon Tet.	0.488E-03	0.283E-03	-42.0
Chromium +6	0.163E-05	0.944E-06	-42.1
Chloroform	0.778E-03	0.451E-03	-42.0
Chlordane	0.488E-04	0.283E-04	-42.0
Dieldrin	0.326E-05	0.189E-05	-42.1
Lead	0.271E-02	0.157E-02	-41.9
Mercury	0.326E-02	0.189E-02	-42.1
Nickel	0.597E-04	0.346E-04	-42.0
PCBs	0.832E-05	0.483E-05	-42.0
Toxaphene	0.561E-04	0.325E-04	-42.0
Vinyl Chloride	0.253E-02	0.147E-02	-41.9

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: \ISC\ISCLT\RENO.OUT

CASE 23

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	82.75	21.85	7.10	2.50
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.532E-05	0.201E-04	0.620E-04	0.176E-03
Arsenic	0.556E-05	0.211E-04	0.648E-04	0.184E-03
Benzo(A)pyrene	0.138E-04	0.522E-04	0.161E-03	0.455E-03
Beryllium	0.102E-04	0.384E-04	0.118E-03	0.336E-03
Bis(2 ethyl Hexyl)	0.599E-02	0.227E-01	0.699E-01	0.198E+00
Cadmium	0.138E-04	0.522E-04	0.161E-03	0.455E-03
Carbon Tet.	0.653E-03	0.247E-02	0.760E-02	0.216E-01
Chromium +6	0.218E-05	0.824E-05	0.253E-04	0.719E-04
Chloroform	0.104E-02	0.394E-02	0.121E-01	0.343E-01
Chlordane	0.653E-04	0.247E-03	0.760E-03	0.216E-02
Dieldrin	0.435E-05	0.165E-04	0.507E-04	0.144E-03
Lead	0.363E-02	0.137E-01	0.422E-01	0.120E+00
Mercury	0.435E-02	0.165E-01	0.507E-01	0.144E+00
Nickel	0.798E-04	0.302E-03	0.929E-03	0.264E-02
PCBs	0.111E-04	0.421E-04	0.130E-03	0.367E-03
Toxaphene	0.749E-04	0.284E-03	0.873E-03	0.248E-02
Vinyl Chloride	0.338E-02	0.128E-01	0.394E-01	0.112E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 23	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.532E-05	33.6
Arsenic	0.416E-05	0.556E-05	33.6
Benzo(A)pyrene	0.103E-04	0.138E-04	33.8
Beryllium	0.760E-05	0.102E-04	33.6
Bis(2 ethyl Hexyl)	0.449E-02	0.599E-02	33.5
Cadmium	0.103E-04	0.138E-04	33.8
Carbon Tet.	0.488E-03	0.653E-03	33.7
Chromium +6	0.163E-05	0.218E-05	33.4
Chloroform	0.778E-03	0.104E-02	33.6
Chlordane	0.488E-04	0.653E-04	33.7
Dieldrin	0.326E-05	0.435E-05	33.4
Lead	0.271E-02	0.363E-02	33.8
Mercury	0.326E-02	0.435E-02	33.4
Nickel	0.597E-04	0.798E-04	33.6
PCBs	0.832E-05	0.111E-04	33.6
Toxaphene	0.561E-04	0.749E-04	33.6
Vinyl Chloride	0.253E-02	0.338E-02	33.7

07/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: \ISC\ISCLT\TACOMA.OUT

CASE 24

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	148.36	53.48	15.41	5.18
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.297E-05	0.823E-05	0.285E-04	0.850E-04
Arsenic	0.310E-05	0.860E-05	0.298E-04	0.888E-04
Benzo(A)pyrene	0.768E-05	0.213E-04	0.740E-04	0.220E-03
Beryllium	0.566E-05	0.157E-04	0.545E-04	0.162E-03
Bis(2 ethyl Hexyl)	0.334E-02	0.927E-02	0.322E-01	0.958E-01
Cadmium	0.768E-05	0.213E-04	0.740E-04	0.220E-03
Carbon Tet.	0.364E-03	0.101E-02	0.350E-02	0.104E-01
Chromium +6	0.121E-05	0.337E-05	0.117E-04	0.348E-04
Chloroform	0.580E-03	0.161E-02	0.558E-02	0.166E-01
Chlordane	0.364E-04	0.101E-03	0.350E-03	0.104E-02
Dieldrin	0.243E-05	0.673E-05	0.234E-04	0.695E-04
Lead	0.202E-02	0.561E-02	0.195E-01	0.579E-01
Mercury	0.243E-02	0.673E-02	0.234E-01	0.695E-01
Nickel	0.445E-04	0.123E-03	0.428E-03	0.127E-02
PCBs	0.620E-05	0.172E-04	0.597E-04	0.178E-03
Toxaphene	0.418E-04	0.116E-03	0.402E-03	0.120E-02
Vinyl Chloride	0.189E-02	0.524E-02	0.182E-01	0.541E-01

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 24	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.297E-05	-25.5
Arsenic	0.416E-05	0.310E-05	-25.5
Benzo(A)pyrene	0.103E-04	0.768E-05	-25.4
Beryllium	0.760E-05	0.566E-05	-25.5
Bis(2 ethyl Hexyl)	0.449E-02	0.334E-02	-25.5
Cadmium	0.103E-04	0.768E-05	-25.4
Carbon Tet.	0.488E-03	0.364E-03	-25.4
Chromium +6	0.163E-05	0.121E-05	-25.6
Chloroform	0.778E-03	0.580E-03	-25.5
Chlordane	0.488E-04	0.364E-04	-25.4
Dieldrin	0.326E-05	0.243E-05	-25.6
Lead	0.271E-02	0.202E-02	-25.4
Mercury	0.326E-02	0.243E-02	-25.6
Nickel	0.597E-04	0.445E-04	-25.5
PCBs	0.832E-05	0.620E-05	-25.5
Toxaphene	0.561E-04	0.418E-04	-25.5
Vinyl Chloride	0.253E-02	0.189E-02	-25.4

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

FILE USED: ISCTST25.OUT

CASE 25

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	54.97	16.61	4.89	1.67
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.800E-05	0.265E-04	0.901E-04	0.263E-03
Arsenic	0.837E-05	0.277E-04	0.941E-04	0.275E-03
Benzo(A)pyrene	0.207E-04	0.686E-04	0.233E-03	0.681E-03
Beryllium	0.153E-04	0.506E-04	0.172E-03	0.502E-03
Bis(2 ethyl Hexyl)	0.902E-02	0.299E-01	0.102E+00	0.296E+00
Cadmium	0.207E-04	0.686E-04	0.233E-03	0.681E-03
Carbon Tet.	0.982E-03	0.325E-02	0.111E-01	0.323E-01
Chromium +6	0.327E-05	0.108E-04	0.368E-04	0.108E-03
Chloroform	0.156E-02	0.518E-02	0.176E-01	0.514E-01
Chlordane	0.982E-04	0.325E-03	0.111E-02	0.323E-02
Dieldrin	0.655E-05	0.217E-04	0.737E-04	0.215E-03
Lead	0.546E-02	0.181E-01	0.614E-01	0.179E+00
Mercury	0.655E-02	0.217E-01	0.737E-01	0.215E+00
Nickel	0.120E-03	0.397E-03	0.135E-02	0.394E-02
PCBs	0.167E-04	0.554E-04	0.188E-03	0.550E-03
Toxaphene	0.113E-03	0.373E-03	0.127E-02	0.371E-02
Vinyl Chloride	0.509E-02	0.169E-01	0.573E-01	0.167E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 25	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.800E-05	101.1
Arsenic	0.416E-05	0.837E-05	101.2
Benzo(A)pyrene	0.103E-04	0.207E-04	101.3
Beryllium	0.760E-05	0.153E-04	101.1
Bis(2 ethyl Hexyl)	0.449E-02	0.902E-02	101.0
Cadmium	0.103E-04	0.207E-04	101.3
Carbon Tet.	0.488E-03	0.982E-03	101.3
Chromium +6	0.163E-05	0.327E-05	100.9
Chloroform	0.778E-03	0.156E-02	101.1
Chlordane	0.488E-04	0.982E-04	101.3
Dieldrin	0.326E-05	0.655E-05	100.9
Lead	0.271E-02	0.546E-02	101.4
Mercury	0.326E-02	0.655E-02	100.9
Nickel	0.597E-04	0.120E-03	101.1
PCBs	0.832E-05	0.167E-04	101.2
Toxaphene	0.561E-04	0.113E-03	101.1
Vinyl Chloride	0.253E-02	0.509E-02	101.3

07/20/87 ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA PAGE: 1

FILE USED: ISCTST26.OUT

CASE 26

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	30.03	13.16	4.62	1.61
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.147E-04	0.334E-04	0.953E-04	0.273E-03
Arsenic	0.153E-04	0.350E-04	0.996E-04	0.285E-03
Benzo(A)pyrene	0.380E-04	0.866E-04	0.247E-03	0.707E-03
Beryllium	0.280E-04	0.638E-04	0.182E-03	0.521E-03
Bis(2 ethyl Hexyl)	0.165E-01	0.377E-01	0.107E+00	0.308E+00
Cadmium	0.380E-04	0.866E-04	0.247E-03	0.707E-03
Carbon Tet.	0.180E-02	0.410E-02	0.117E-01	0.335E-01
Chromium +6	0.599E-05	0.137E-04	0.390E-04	0.112E-03
Chloroform	0.286E-02	0.654E-02	0.186E-01	0.533E-01
Chlordane	0.180E-03	0.410E-03	0.117E-02	0.335E-02
Dieldrin	0.120E-04	0.274E-04	0.780E-04	0.223E-03
Lead	0.999E-02	0.228E-01	0.650E-01	0.186E+00
Mercury	0.120E-01	0.274E-01	0.780E-01	0.223E+00
Nickel	0.220E-03	0.502E-03	0.143E-02	0.409E-02
PCBs	0.306E-04	0.699E-04	0.199E-03	0.571E-03
Toxaphene	0.206E-03	0.471E-03	0.134E-02	0.385E-02
Vinyl Chloride	0.932E-02	0.213E-01	0.606E-01	0.174E+00

(a) The maximum distance equals 50.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 26	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.147E-04	268.1
Arsenic	0.416E-05	0.153E-04	268.2
Benzo(A)pyrene	0.103E-04	0.380E-04	268.6
Beryllium	0.760E-05	0.280E-04	268.0
Bis(2 ethyl Hexyl)	0.449E-02	0.165E-01	267.8
Cadmium	0.103E-04	0.380E-04	268.6
Carbon Tet.	0.488E-03	0.180E-02	268.5
Chromium +6	0.163E-05	0.599E-05	267.7
Chloroform	0.778E-03	0.286E-02	268.1
Chlordane	0.488E-04	0.180E-03	268.5
Dieldrin	0.326E-05	0.120E-04	267.7
Lead	0.271E-02	0.999E-02	268.6
Mercury	0.326E-02	0.120E-01	267.7
Nickel	0.597E-04	0.220E-03	268.1
PCBs	0.832E-05	0.306E-04	268.2
Toxaphene	0.561E-04	0.206E-03	268.0
Vinyl Chloride	0.253E-02	0.932E-02	268.5

07/20/87 ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA PAGE: 1

FILE USED: ISCTST27.OUT

CASE 27

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	25.18	12.21	4.37	1.54
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.175E-04	0.360E-04	0.101E-03	0.286E-03
Arsenic	0.183E-04	0.377E-04	0.105E-03	0.299E-03
Benzo(A)pyrene	0.453E-04	0.933E-04	0.261E-03	0.740E-03
Beryllium	0.334E-04	0.688E-04	0.192E-03	0.546E-03
Bis(2 ethyl Hexyl)	0.197E-01	0.406E-01	0.114E+00	0.322E+00
Cadmium	0.453E-04	0.933E-04	0.261E-03	0.740E-03
Carbon Tet.	0.214E-02	0.442E-02	0.124E-01	0.351E-01
Chromium +6	0.715E-05	0.147E-04	0.412E-04	0.117E-03
Chloroform	0.341E-02	0.704E-02	0.197E-01	0.559E-01
Chlordane	0.214E-03	0.442E-03	0.124E-02	0.351E-02
Dieldrin	0.143E-04	0.295E-04	0.824E-04	0.234E-03
Lead	0.119E-01	0.246E-01	0.687E-01	0.195E+00
Mercury	0.143E-01	0.295E-01	0.824E-01	0.234E+00
Nickel	0.262E-03	0.540E-03	0.151E-02	0.429E-02
PCBs	0.365E-04	0.753E-04	0.211E-03	0.597E-03
Toxaphene	0.246E-03	0.508E-03	0.142E-02	0.403E-02
Vinyl Chloride	0.111E-01	0.229E-01	0.641E-01	0.182E+00

(a) The maximum distance equals 100.000 meters.

EMISSION RATES BASED ON MAXIMUM
GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 27	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.175E-04	339.0
Arsenic	0.416E-05	0.183E-04	339.1
Benzo(A)pyrene	0.103E-04	0.453E-04	339.5
Beryllium	0.760E-05	0.334E-04	338.9
Bis(2 ethyl Hexyl)	0.449E-02	0.197E-01	338.7
Cadmium	0.103E-04	0.453E-04	339.5
Carbon Tet.	0.488E-03	0.214E-02	339.4
Chromium +6	0.163E-05	0.715E-05	338.5
Chloroform	0.778E-03	0.341E-02	338.9
Chlordane	0.488E-04	0.214E-03	339.4
Dieldrin	0.326E-05	0.143E-04	338.5
Lead	0.271E-02	0.119E-01	339.6
Mercury	0.326E-02	0.143E-01	338.5
Nickel	0.597E-04	0.262E-03	339.0
PCBs	0.832E-05	0.365E-04	339.1
Toxaphene	0.561E-04	0.246E-03	338.8
Vinyl Chloride	0.253E-02	0.111E-01	339.5

7/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

ILE USED: ISCTST28.OUT

CASE 28

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	28.65	17.52	5.11	1.61
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.154E-04	0.251E-04	0.862E-04	0.273E-03
Arsenic	0.161E-04	0.263E-04	0.901E-04	0.286E-03
Benzo(A)pyrene	0.398E-04	0.651E-04	0.223E-03	0.708E-03
Beryllium	0.293E-04	0.480E-04	0.165E-03	0.522E-03
Bis(2 ethyl Hexyl)	0.173E-01	0.283E-01	0.971E-01	0.308E+00
Cadmium	0.398E-04	0.651E-04	0.223E-03	0.708E-03
Carbon Tet.	0.188E-02	0.308E-02	0.106E-01	0.335E-01
Chromium +6	0.628E-05	0.103E-04	0.353E-04	0.112E-03
Chloroform	0.300E-02	0.491E-02	0.168E-01	0.534E-01
Chlordane	0.188E-03	0.308E-03	0.106E-02	0.335E-02
Dieldrin	0.126E-04	0.206E-04	0.705E-04	0.224E-03
Lead	0.105E-01	0.171E-01	0.588E-01	0.186E+00
Mercury	0.126E-01	0.206E-01	0.705E-01	0.224E+00
Nickel	0.230E-03	0.377E-03	0.129E-02	0.410E-02
PCBs	0.321E-04	0.525E-04	0.180E-03	0.571E-03
Toxaphene	0.216E-03	0.354E-03	0.121E-02	0.385E-02
Vinyl Chloride	0.977E-02	0.160E-01	0.548E-01	0.174E+00

(a) The maximum distance equals 100.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 28	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.154E-04	285.8
Arsenic	0.416E-05	0.161E-04	285.9
Benzo(A)pyrene	0.103E-04	0.398E-04	286.3
Beryllium	0.760E-05	0.293E-04	285.7
Bis(2 ethyl Hexyl)	0.449E-02	0.173E-01	285.5
Cadmium	0.103E-04	0.398E-04	286.3
Carbon Tet.	0.488E-03	0.188E-02	286.2
Chromium +6	0.163E-05	0.628E-05	285.4
Chloroform	0.778E-03	0.300E-02	285.8
Chlordane	0.488E-04	0.188E-03	286.2
Dieldrin	0.326E-05	0.126E-04	285.4
Lead	0.271E-02	0.105E-01	286.4
Mercury	0.326E-02	0.126E-01	285.4
Nickel	0.597E-04	0.230E-03	285.8
PCBs	0.832E-05	0.321E-04	285.9
Toxaphene	0.561E-04	0.216E-03	285.7
Vinyl Chloride	0.253E-02	0.977E-02	286.3

7/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS
FROM SLUDGE INCINERATORS CALCULATED USING
THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
QUALITY CRITERIA

ILE USED: ISCTST29.OUT

CASE 29

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	14.57	8.89	3.48	1.34
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.302E-04	0.495E-04	0.126E-03	0.328E-03
Arsenic	0.316E-04	0.517E-04	0.132E-03	0.343E-03
Benzo(A)pyrene	0.783E-04	0.128E-03	0.327E-03	0.849E-03
Beryllium	0.577E-04	0.945E-04	0.241E-03	0.625E-03
Bis(2 ethyl Hexyl)	0.341E-01	0.558E-01	0.142E+00	0.369E+00
Cadmium	0.783E-04	0.128E-03	0.327E-03	0.849E-03
Carbon Tet.	0.371E-02	0.607E-02	0.155E-01	0.402E-01
Chromium +6	0.124E-04	0.202E-04	0.517E-04	0.134E-03
Chloroform	0.590E-02	0.967E-02	0.247E-01	0.640E-01
Chlordane	0.371E-03	0.607E-03	0.155E-02	0.402E-02
Dieldrin	0.247E-04	0.405E-04	0.103E-03	0.268E-03
Lead	0.206E-01	0.337E-01	0.861E-01	0.223E+00
Mercury	0.247E-01	0.405E-01	0.103E+00	0.268E+00
Nickel	0.453E-03	0.742E-03	0.189E-02	0.491E-02
PCBs	0.632E-04	0.103E-03	0.264E-03	0.685E-03
Toxaphene	0.426E-03	0.697E-03	0.178E-02	0.462E-02
Vinyl Chloride	0.192E-01	0.315E-01	0.804E-01	0.208E+00

(a) The maximum distance equals 100.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 29	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.302E-04	659.0
Arsenic	0.416E-05	0.316E-04	659.2
Benzo(A)pyrene	0.103E-04	0.783E-04	659.9
Beryllium	0.760E-05	0.577E-04	658.8
Bis(2 ethyl Hexyl)	0.449E-02	0.341E-01	658.4
Cadmium	0.103E-04	0.783E-04	659.9
Carbon Tet.	0.488E-03	0.371E-02	659.7
Chromium +6	0.163E-05	0.124E-04	658.1
Chloroform	0.778E-03	0.590E-02	658.9
Chlordane	0.488E-04	0.371E-03	659.7
Dieldrin	0.326E-05	0.247E-04	658.1
Lead	0.271E-02	0.206E-01	660.0
Mercury	0.326E-02	0.247E-01	658.1
Nickel	0.597E-04	0.453E-03	659.0
PCBs	0.832E-05	0.632E-04	659.2
Toxaphene	0.561E-04	0.426E-03	658.7
Vinyl Chloride	0.253E-02	0.192E-01	659.8

```
7/20/87        ALLOWABLE EMISSION RATES FOR POLLUTANTS        PAGE:  1
               FROM SLUDGE INCINERATORS CALCULATED USING
               THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR
                          QUALITY CRITERIA
ILE USED: ISCTST30.OUT
```

CASE 30

```
------------------------------------------------------------------------------------------
                       | ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES,
                       |          MICROGRAMS/M**3
                       |
                       |------------------------------------------------------------------
                       |  MAXIMUM     |    200m      |    500m      |    1000m
                       | DISTANCE(a)  |______________|______________|____________________
                       |              |              |              |
                       |   11.74      |    8.21      |    3.40      |    1.29
                       |______________|______________|______________|____________________
                       |
 POLLUTANT NAME        |  ALLOWABLE EMISSION RATES, g/s
                       |
-----------------------------------------------------------------------------------------
 Aldrin                | 0.375E-04    | 0.536E-04    | 0.130E-03    | 0.340E-03
 Arsenic               | 0.392E-04    | 0.560E-04    | 0.135E-03    | 0.356E-03
 Benzo(A)pyrene        | 0.971E-04    | 0.139E-03    | 0.336E-03    | 0.881E-03
 Beryllium             | 0.716E-04    | 0.102E-03    | 0.247E-03    | 0.649E-03
 Bis(2 ethyl Hexyl)    | 0.423E-01    | 0.604E-01    | 0.146E+00    | 0.383E+00
 Cadmium               | 0.971E-04    | 0.139E-03    | 0.336E-03    | 0.881E-03
 Carbon Tet.           | 0.460E-02    | 0.658E-02    | 0.159E-01    | 0.417E-01
 Chromium +6           | 0.153E-04    | 0.219E-04    | 0.530E-04    | 0.139E-03
 Chloroform            | 0.733E-02    | 0.105E-01    | 0.253E-01    | 0.665E-01
 Chlordane             | 0.460E-03    | 0.658E-03    | 0.159E-02    | 0.417E-02
 Dieldrin              | 0.307E-04    | 0.438E-04    | 0.106E-03    | 0.278E-03
 Lead                  | 0.256E-01    | 0.365E-01    | 0.883E-01    | 0.232E+00
 Mercury               | 0.307E-01    | 0.438E-01    | 0.106E+00    | 0.278E+00
 Nickel                | 0.562E-03    | 0.804E-03    | 0.194E-02    | 0.510E-02
 PCBs                  | 0.784E-04    | 0.112E-03    | 0.271E-03    | 0.711E-03
 Toxaphene             | 0.528E-03    | 0.755E-03    | 0.182E-02    | 0.479E-02
 Vinyl Chloride        | 0.239E-01    | 0.341E-01    | 0.824E-01    | 0.216E+00

      (a) The maximum distance equals   100.000 meters.
```

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 30	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.375E-04	841.8
Arsenic	0.416E-05	0.392E-04	842.0
Benzo(A)pyrene	0.103E-04	0.971E-04	842.9
Beryllium	0.760E-05	0.716E-04	841.6
Bis(2 ethyl Hexyl)	0.449E-02	0.423E-01	841.1
Cadmium	0.103E-04	0.971E-04	842.9
Carbon Tet.	0.488E-03	0.460E-02	842.7
Chromium +6	0.163E-05	0.153E-04	840.8
Chloroform	0.778E-03	0.733E-02	841.7
Chlordane	0.488E-04	0.460E-03	842.7
Dieldrin	0.326E-05	0.307E-04	840.8
Lead	0.271E-02	0.256E-01	843.1
Mercury	0.326E-02	0.307E-01	840.8
Nickel	0.597E-04	0.562E-03	841.8
PCBs	0.832E-05	0.784E-04	842.0
Toxaphene	0.561E-04	0.528E-03	841.5
Vinyl Chloride	0.253E-02	0.239E-01	842.9

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

ILE USED: ISCTST31.OUT

CASE 31

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	4.87	4.87	2.12	0.97
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.903E-04	0.903E-04	0.208E-03	0.453E-03
Arsenic	0.944E-04	0.944E-04	0.217E-03	0.473E-03
Benzo(A)pyrene	0.234E-03	0.234E-03	0.538E-03	0.117E-02
Beryllium	0.172E-03	0.172E-03	0.396E-03	0.864E-03
Bis(2 ethyl Hexyl)	0.102E+00	0.102E+00	0.234E+00	0.510E+00
Cadmium	0.234E-03	0.234E-03	0.538E-03	0.117E-02
Carbon Tet.	0.111E-01	0.111E-01	0.255E-01	0.556E-01
Chromium +6	0.370E-04	0.370E-04	0.849E-04	0.185E-03
Chloroform	0.177E-01	0.177E-01	0.406E-01	0.885E-01
Chlordane	0.111E-02	0.111E-02	0.255E-02	0.556E-02
Dieldrin	0.739E-04	0.739E-04	0.170E-03	0.370E-03
Lead	0.616E-01	0.616E-01	0.142E+00	0.309E+00
Mercury	0.739E-01	0.739E-01	0.170E+00	0.370E+00
Nickel	0.136E-02	0.136E-02	0.311E-02	0.679E-02
PCBs	0.189E-03	0.189E-03	0.434E-03	0.947E-03
Toxaphene	0.127E-02	0.127E-02	0.293E-02	0.638E-02
Vinyl Chloride	0.575E-01	0.575E-01	0.132E+00	0.288E+00

(a) The maximum distance equals 200.000 meters.

EMISSION RATES BASED ON MAXIMUM
GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 31	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.903E-04	2169.8
Arsenic	0.416E-05	0.944E-04	2170.3
Benzo(A)pyrene	0.103E-04	0.234E-03	2172.4
Beryllium	0.760E-05	0.172E-03	2169.2
Bis(2 ethyl Hexyl)	0.449E-02	0.102E+00	2168.0
Cadmium	0.103E-04	0.234E-03	2172.4
Carbon Tet.	0.488E-03	0.111E-01	2171.9
Chromium +6	0.163E-05	0.370E-04	2167.2
Chloroform	0.778E-03	0.177E-01	2169.5
Chlordane	0.488E-04	0.111E-02	2171.9
Dieldrin	0.326E-05	0.739E-04	2167.2
Lead	0.271E-02	0.616E-01	2172.8
Mercury	0.326E-02	0.739E-01	2167.2
Nickel	0.597E-04	0.136E-02	2169.8
PCBs	0.832E-05	0.189E-03	2170.3
Toxaphene	0.561E-04	0.127E-02	2169.0
Vinyl Chloride	0.253E-02	0.575E-01	2172.2

7/20/87

ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA

ILE USED: ISCTST32.OUT

CASE 32

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	1.37	1.05	1.02	0.54
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.321E-03	0.419E-03	0.433E-03	0.808E-03
Arsenic	0.336E-03	0.438E-03	0.453E-03	0.845E-03
Benzo(A)pyrene	0.832E-03	0.108E-02	0.112E-02	0.209E-02
Beryllium	0.613E-03	0.799E-03	0.827E-03	0.154E-02
Bis(2 ethyl Hexyl)	0.362E+00	0.472E+00	0.488E+00	0.911E+00
Cadmium	0.832E-03	0.108E-02	0.112E-02	0.209E-02
Carbon Tet.	0.394E-01	0.514E-01	0.532E-01	0.992E-01
Chromium +6	0.131E-03	0.171E-03	0.177E-03	0.331E-03
Chloroform	0.628E-01	0.818E-01	0.846E-01	0.158E+00
Chlordane	0.394E-02	0.514E-02	0.532E-02	0.992E-02
Dieldrin	0.263E-03	0.343E-03	0.354E-03	0.661E-03
Lead	0.219E+00	0.285E+00	0.295E+00	0.551E+00
Mercury	0.263E+00	0.343E+00	0.354E+00	0.661E+00
Nickel	0.482E-02	0.628E-02	0.650E-02	0.121E-01
PCBs	0.672E-03	0.875E-03	0.906E-03	0.169E-02
Toxaphene	0.453E-02	0.590E-02	0.610E-02	0.114E-01
Vinyl Chloride	0.204E+00	0.266E+00	0.276E+00	0.514E+00

(a) The maximum distance equals 300.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 32	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.321E-03	7969.6
Arsenic	0.416E-05	0.336E-03	7971.4
Benzo(A)pyrene	0.103E-04	0.832E-03	7978.9
Beryllium	0.760E-05	0.613E-03	7967.7
Bis(2 ethyl Hexyl)	0.449E-02	0.362E+00	7963.4
Cadmium	0.103E-04	0.832E-03	7978.9
Carbon Tet.	0.488E-03	0.394E-01	7977.1
Chromium +6	0.163E-05	0.131E-03	7960.6
Chloroform	0.778E-03	0.628E-01	7968.7
Chlordane	0.488E-04	0.394E-02	7977.1
Dieldrin	0.326E-05	0.263E-03	7960.6
Lead	0.271E-02	0.219E+00	7980.4
Mercury	0.326E-02	0.263E+00	7960.6
Nickel	0.597E-04	0.482E-02	7969.6
PCBs	0.832E-05	0.672E-03	7971.4
Toxaphene	0.561E-04	0.453E-02	7967.0
Vinyl Chloride	0.253E-02	0.204E+00	7978.3

7/20/87 ALLOWABLE EMISSION RATES FOR POLLUTANTS FROM SLUDGE INCINERATORS CALCULATED USING THE ISCLT MODEL AND INCREMENTAL ANNUAL AIR QUALITY CRITERIA PAGE: 1

ILE USED: \ISC\ISCLT\ISCTST33.OUT

CASE 33

	ISCLT CONCENTRATIONS AT VARIOUS DOWNWIND DISTANCES, MICROGRAMS/M**3			
	MAXIMUM DISTANCE(a)	200m	500m	1000m
	1.12	0.74	0.87	0.46
POLLUTANT NAME	ALLOWABLE EMISSION RATES, g/s			
Aldrin	0.394E-03	0.591E-03	0.503E-03	0.952E-03
Arsenic	0.412E-03	0.618E-03	0.526E-03	0.996E-03
Benzo(A)pyrene	0.102E-02	0.153E-02	0.130E-02	0.247E-02
Beryllium	0.752E-03	0.113E-02	0.961E-03	0.182E-02
Bis(2 ethyl Hexyl)	0.444E+00	0.666E+00	0.567E+00	0.107E+01
Cadmium	0.102E-02	0.153E-02	0.130E-02	0.247E-02
Carbon Tet.	0.484E-01	0.725E-01	0.617E-01	0.117E+00
Chromium +6	0.161E-03	0.242E-03	0.206E-03	0.390E-03
Chloroform	0.770E-01	0.115E+00	0.983E-01	0.186E+00
Chlordane	0.484E-02	0.725E-02	0.617E-02	0.117E-01
Dieldrin	0.322E-03	0.483E-03	0.412E-03	0.779E-03
Lead	0.269E+00	0.403E+00	0.343E+00	0.649E+00
Mercury	0.322E+00	0.483E+00	0.412E+00	0.779E+00
Nickel	0.591E-02	0.886E-02	0.755E-02	0.143E-01
PCBs	0.824E-03	0.124E-02	0.105E-02	0.199E-02
Toxaphene	0.555E-02	0.833E-02	0.709E-02	0.134E-01
Vinyl Chloride	0.251E+00	0.376E+00	0.320E+00	0.606E+00

(a) The maximum distance equals 300.000 meters.

EMISSION RATES BASED ON MAXIMUM GROUND-LEVEL ISCLT MODEL CALCULATIONS

POLLUTANT	BASE CASE ALLOWABLE EMISSION RATE, g/s	TESTCASE NO. 33	
		EMISSION RATE, g/s	PERCENT DIFFERENCE
Aldrin	0.398E-05	0.394E-03	9801.5
Arsenic	0.416E-05	0.412E-03	9803.7
Benzo(A)pyrene	0.103E-04	0.102E-02	9812.9
Beryllium	0.760E-05	0.752E-03	9799.1
Bis(2 ethyl Hexyl)	0.449E-02	0.444E+00	9793.9
Cadmium	0.103E-04	0.102E-02	9812.9
Carbon Tet.	0.488E-03	0.484E-01	9810.7
Chromium +6	0.163E-05	0.161E-03	9790.5
Chloroform	0.778E-03	0.770E-01	9800.4
Chlordane	0.488E-04	0.484E-02	9810.7
Dieldrin	0.326E-05	0.322E-03	9790.5
Lead	0.271E-02	0.269E+00	9814.8
Mercury	0.326E-02	0.322E+00	9790.5
Nickel	0.597E-04	0.591E-02	9801.5
PCBs	0.832E-05	0.824E-03	9803.7
Toxaphene	0.561E-04	0.555E-02	9798.3
Vinyl Chloride	0.253E-02	0.251E+00	9812.2

APPENDIX B

TABULATION OF MAXIMUM ALLOWABLE CONCENTRATIONS AND PERCENT DIFFERENCES BY CHEMICAL CONSTITUENT

Aldrin

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE			200 m			500 m			1000 m		
	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.398E-05	0.121E-02	0.303E+05	0.208E-04	0.145E-01	0.695E+05	0.811E-04	0.121E-02	0.139E+04	0.249E-03	0.173E-02	0.593E+03
TEST 2	0.398E-05	0.336E-02	0.844E+05	0.208E-04	0.411E+01	0.198E+08	0.811E-04	0.625E-02	0.760E+04	0.249E-03	0.336E-02	0.125E+04
TEST 3	0.398E-05	0.387E-04	0.872E+03	0.208E-04	0.554E-04	0.166E+03	0.811E-04	0.137E-03	0.688E+02	0.249E-03	0.347E-03	0.393E+02
TEST 4	0.398E-05	0.113E-03	0.273E+04	0.208E-04	0.113E-03	0.442E+03	0.811E-04	0.213E-03	0.163E+03	0.249E-03	0.442E-03	0.775E+02
TEST 5	0.398E-05	0.639E-05	0.606E+02	0.208E-04	0.229E-04	0.102E+02	0.811E-04	0.820E-04	0.116E+01	0.249E-03	0.249E-03	-.169E+00
TEST 6	0.398E-05	0.174E-04	0.336E+03	0.208E-04	0.372E-04	0.788E+02	0.811E-04	0.106E-03	0.303E+02	0.249E-03	0.277E-03	0.111E+02
TEST 7	0.398E-05	0.547E-05	0.373E+02	0.208E-04	0.430E-04	0.107E+03	0.811E-04	0.192E-03	0.137E+03	0.249E-03	0.613E-03	0.146E+03
TEST 8	0.398E-05	0.352E-05	-.116E+02	0.208E-04	0.168E-04	-.190E+02	0.811E-04	0.661E-04	-.185E+02	0.249E-03	0.205E-03	-.176E+02
TEST 9	0.398E-05	0.460E-05	0.156E+02	0.208E-04	0.189E-04	-.911E+01	0.811E-04	0.635E-04	-.218E+02	0.249E-03	0.185E-03	-.255E+02
TEST 10	0.398E-05	0.412E-05	0.355E+01	0.208E-04	0.230E-04	0.105E+02	0.811E-04	0.936E-04	0.154E+02	0.249E-03	0.295E-03	0.186E+02
TEST 11	0.398E-05	0.478E-05	0.202E+02	0.208E-04	0.235E-04	0.128E+02	0.811E-04	0.834E-04	0.289E+01	0.249E-03	0.249E-03	-.200E+00
TEST 12	0.398E-05	0.340E-05	-.145E+02	0.208E-04	0.122E-04	-.412E+02	0.811E-04	0.420E-04	-.482E+02	0.249E-03	0.123E-03	-.505E+02
TEST 13	0.398E-05	0.442E-05	0.110E+02	0.208E-04	0.252E-04	0.213E+02	0.811E-04	0.100E-03	0.238E+02	0.249E-03	0.312E-03	0.251E+02
TEST 14	0.398E-05	0.500E-05	0.256E+02	0.208E-04	0.217E-04	0.422E+01	0.811E-04	0.787E-04	-.297E+01	0.249E-03	0.238E-03	-.460E+01
TEST 15	0.398E-05	0.296E-05	-.256E+02	0.208E-04	0.193E-04	-.738E+01	0.811E-04	0.810E-04	-.181E+00	0.249E-03	0.255E-03	0.258E+01
TEST 16	0.398E-05	0.487E-05	0.224E+02	0.208E-04	0.257E-04	0.234E+02	0.811E-04	0.995E-04	0.227E+02	0.249E-03	0.302E-03	0.212E+02
TEST 17	0.398E-05	0.344E-05	-.137E+02	0.208E-04	0.192E-04	-.774E+01	0.811E-04	0.775E-04	-.446E+01	0.249E-03	0.243E-03	-.253E+01
TEST 18	0.398E-05	0.427E-05	0.729E+01	0.208E-04	0.261E-04	0.254E+02	0.811E-04	0.107E-03	0.321E+02	0.249E-03	0.336E-03	0.351E+02
TEST 19	0.398E-05	0.237E-05	-.404E+02	0.208E-04	0.135E-04	-.351E+02	0.811E-04	0.457E-04	-.436E+02	0.249E-03	0.134E-03	-.462E+02

TEST 20	0.390E-05	0.486E-05	0.221E+02	0.208E-04	0.243E-04	0.170E+02	0.811E-04	0.949E-04	0.170E+02	0.249E-03	0.289E-03	0.159E+02
TEST 21	0.390E-05	0.334E-05	-.161E+02	0.208E-04	0.146E-04	-.299E+02	0.811E-04	0.493E-04	-.393E+02	0.249E-03	0.142E-03	-.430E+02
TEST 22	0.390E-05	0.231E-05	-.420E+02	0.208E-04	0.134E-04	-.356E+02	0.811E-04	0.559E-04	-.310E+02	0.249E-03	0.178E-03	-.283E+02
TEST 23	0.390E-05	0.532E-05	0.336E+02	0.208E-04	0.201E-04	-.310E+01	0.811E-04	0.620E-04	-.236E+02	0.249E-03	0.176E-03	-.294E+02
TEST 24	0.390E-05	0.297E-05	-.255E+02	0.208E-04	0.823E-05	-.604E+02	0.811E-04	0.285E-04	-.648E+02	0.249E-03	0.850E-04	-.659E+02
TEST 25	0.390E-05	0.800E-05	0.101E+03	0.208E-04	0.265E-04	0.274E+02	0.811E-04	0.901E-04	0.110E+02	0.249E-03	0.263E-03	0.560E+01
TEST 26	0.390E-05	0.147E-04	0.268E+03	0.208E-04	0.334E-04	0.600E+02	0.811E-04	0.953E-04	0.175E+02	0.249E-03	0.273E-03	0.960E+01
TEST 27	0.390E-05	0.175E-04	0.339E+03	0.208E-04	0.360E-04	0.732E+02	0.811E-04	0.101E-03	0.242E+02	0.249E-03	0.286E-03	0.140E+02
TEST 28	0.390E-05	0.154E-04	0.286E+03	0.208E-04	0.251E-04	0.208E+02	0.811E-04	0.862E-04	0.625E+01	0.249E-03	0.273E-03	0.974E+01
TEST 29	0.390E-05	0.302E-04	0.659E+03	0.208E-04	0.495E-04	0.130E+03	0.811E-04	0.126E-03	0.557E+02	0.249E-03	0.328E-03	0.316E+02
TEST 30	0.390E-05	0.375E-04	0.842E+03	0.208E-04	0.536E-04	0.158E+03	0.811E-04	0.130E-03	0.597E+02	0.249E-03	0.340E-03	0.366E+02
TEST 31	0.390E-05	0.903E-04	0.217E+04	0.208E-04	0.903E-04	0.334E+03	0.811E-04	0.208E-03	0.156E+03	0.249E-03	0.453E-03	0.819E+02
TEST 32	0.390E-05	0.321E-03	0.797E+04	0.208E-04	0.419E-03	0.191E+04	0.811E-04	0.433E-03	0.434E+03	0.249E-03	0.806E-03	0.225E+03
TEST 33	0.390E-05	0.394E-03	0.900E+04	0.208E-04	0.591E-03	0.274E+04	0.811E-04	0.503E-03	0.520E+03	0.249E-03	0.952E-03	0.282E+03

Arsenic

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE BASE ALLOW RATE	MAXIMUM DISTANCE ALLOW RATE	MAXIMUM DISTANCE % DIFF	200 m BASE ALLOW RATE	200 m ALLOW RATE	200 m % DIFF	500 m BASE ALLOW RATE	500 m ALLOW RATE	500 m % DIFF	1000 m BASE ALLOW RATE	1000 m ALLOW RATE	1000 m % DIFF
TEST 1	0.416E-05	0.136E-02	0.323E+05	0.218E-04	0.151E-01	0.694E+05	0.847E-04	0.126E-02	0.139E+04	0.260E-03	0.180E-02	0.594E+03
TEST 2	0.416E-05	0.351E-02	0.844E+05	0.218E-04	0.430E+01	0.197E+08	0.847E-04	0.653E-02	0.761E+04	0.260E-03	0.351E-02	0.125E+04
TEST 3	0.416E-05	0.404E-04	0.872E+03	0.218E-04	0.579E-04	0.166E+03	0.847E-04	0.143E-03	0.690E+02	0.260E-03	0.363E-03	0.395E+02
TEST 4	0.416E-05	0.118E-03	0.273E+04	0.218E-04	0.118E-03	0.440E+03	0.847E-04	0.223E-03	0.163E+03	0.260E-03	0.462E-03	0.777E+02
TEST 5	0.416E-05	0.668E-05	0.606E+02	0.218E-04	0.240E-04	0.988E+01	0.847E-04	0.858E-04	0.126E+01	0.260E-03	0.260E-03	-.467E-01
TEST 6	0.416E-05	0.181E-04	0.336E+03	0.218E-04	0.389E-04	0.784E+02	0.847E-04	0.110E-03	0.304E+02	0.260E-03	0.289E-03	0.113E+02
TEST 7	0.416E-05	0.571E-05	0.374E+02	0.218E-04	0.450E-04	0.106E+03	0.847E-04	0.201E-03	0.137E+03	0.260E-03	0.641E-03	0.147E+03
TEST 8	0.416E-05	0.368E-05	-.115E+02	0.218E-04	0.176E-04	-.192E+02	0.847E-04	0.691E-04	-.184E+02	0.260E-03	0.215E-03	-.175E+02
TEST 9	0.416E-05	0.481E-05	0.156E+02	0.218E-04	0.198E-04	-.934E+01	0.847E-04	0.663E-04	-.217E+02	0.260E-03	0.194E-03	-.254E+02
TEST 10	0.416E-05	0.431E-05	0.357E+01	0.218E-04	0.240E-04	0.103E+02	0.847E-04	0.978E-04	0.155E+02	0.260E-03	0.309E-03	0.187E+02
TEST 11	0.416E-05	0.500E-05	0.202E+02	0.218E-04	0.245E-04	0.126E+02	0.847E-04	0.872E-04	0.300E+01	0.260E-03	0.260E-03	-.780E-01
TEST 12	0.416E-05	0.356E-05	-.144E+02	0.218E-04	0.128E-04	-.414E+02	0.847E-04	0.439E-04	-.481E+02	0.260E-03	0.129E-03	-.504E+02
TEST 13	0.416E-05	0.462E-05	0.110E+02	0.218E-04	0.264E-04	0.210E+02	0.847E-04	0.105E-03	0.239E+02	0.260E-03	0.326E-03	0.253E+02
TEST 14	0.416E-05	0.522E-05	0.256E+02	0.218E-04	0.227E-04	0.396E+01	0.847E-04	0.823E-04	-.287E+01	0.260E-03	0.248E-03	-.448E+01
TEST 15	0.416E-05	0.310E-05	-.256E+02	0.218E-04	0.201E-04	-.761E+01	0.847E-04	0.846E-04	-.797E-01	0.260E-03	0.267E-03	0.270E+01
TEST 16	0.416E-05	0.509E-05	0.225E+02	0.218E-04	0.268E-04	0.231E+02	0.847E-04	0.104E-03	0.229E+02	0.260E-03	0.316E-03	0.214E+02
TEST 17	0.416E-05	0.359E-05	-.136E+02	0.218E-04	0.201E-04	-.797E+01	0.847E-04	0.810E-04	-.436E+01	0.260E-03	0.254E-03	-.241E+01
TEST 18	0.416E-05	0.446E-05	0.732E+01	0.218E-04	0.273E-04	0.251E+02	0.847E-04	0.112E-03	0.322E+02	0.260E-03	0.352E-03	0.352E+02
TEST 19	0.416E-05	0.248E-05	-.40[illegible]E+02	0.218E-04	0.141E-04	-.352E+02	0.847E-04	0.476E-04	-.436E+02	0.260E-03	0.140E-03	-.461E+02

C-B-4

TEST 20	0.416E-05	0.508E-05	0.221E+02	0.218E-04	0.254E-04	0.167E+02	0.847E-04	0.992E-04	0.171E+02	0.260E-03	0.302E-03	0.160E+02
TEST 21	0.416E-05	0.349E-05	-.161E+02	0.218E-04	0.153E-04	-.300E+02	0.847E-04	0.515E-04	-.392E+02	0.260E-03	0.148E-03	-.429E+02
TEST 22	0.416E-05	0.241E-05	-.420E+02	0.218E-04	0.140E-04	-.358E+02	0.847E-04	0.585E-04	-.389E+02	0.260E-03	0.187E-03	-.282E+02
TEST 23	0.416E-05	0.556E-05	0.336E+02	0.218E-04	0.211E-04	-.342E+01	0.847E-04	0.648E-04	-.235E+02	0.260E-03	0.184E-03	-.293E+02
TEST 24	0.416E-05	0.310E-05	-.255E+02	0.218E-04	0.860E-05	-.685E+02	0.847E-04	0.298E-04	-.648E+02	0.260E-03	0.888E-04	-.658E+02
TEST 25	0.416E-05	0.837E-05	0.101E+03	0.218E-04	0.277E-04	0.270E+02	0.847E-04	0.941E-04	0.112E+02	0.260E-03	0.275E-03	0.573E+01
TEST 26	0.416E-05	0.153E-04	0.268E+03	0.218E-04	0.350E-04	0.604E+02	0.847E-04	0.996E-04	0.176E+02	0.260E-03	0.285E-03	0.974E+01
TEST 27	0.416E-05	0.183E-04	0.339E+03	0.218E-04	0.377E-04	0.728E+02	0.847E-04	0.105E-03	0.243E+02	0.260E-03	0.299E-03	0.149E+02
TEST 28	0.416E-05	0.161E-04	0.286E+03	0.218E-04	0.263E-04	0.285E+02	0.847E-04	0.901E-04	0.636E+01	0.260E-03	0.286E-03	0.988E+01
TEST 29	0.416E-05	0.316E-04	0.659E+03	0.218E-04	0.517E-04	0.137E+03	0.847E-04	0.132E-03	0.559E+02	0.260E-03	0.343E-03	0.317E+02
TEST 30	0.416E-05	0.392E-04	0.842E+03	0.218E-04	0.560E-04	0.157E+03	0.847E-04	0.135E-03	0.599E+02	0.260E-03	0.356E-03	0.367E+02
TEST 31	0.416E-05	0.944E-04	0.217E+04	0.218E-04	0.944E-04	0.333E+03	0.847E-04	0.217E-03	0.156E+03	0.260E-03	0.473E-03	0.821E+02
TEST 32	0.416E-05	0.336E-03	0.797E+04	0.218E-04	0.430E-03	0.191E+04	0.847E-04	0.453E-03	0.435E+03	0.260E-03	0.845E-03	0.225E+03
TEST 33	0.416E-05	0.412E-03	0.980E+04	0.218E-04	0.618E-03	0.273E+04	0.847E-04	0.526E-03	0.521E+03	0.260E-03	0.996E-03	0.283E+03

Benzo(a)pyrene

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

	MAXIMUM DISTANCE			200 m			500 m			1000 m		
CASE NO.	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.103E-04	0.313E-02	0.303E+05	0.540E-04	0.375E-01	0.694E+05	0.210E-03	0.313E-02	0.139E+04	0.644E-03	0.447E-02	0.594E+03
TEST 2	0.103E-04	0.871E-02	0.845E+05	0.540E-04	0.107E+02	0.197E+08	0.210E-03	0.162E-01	0.761E+04	0.644E-03	0.871E-02	0.125E+04
TEST 3	0.103E-04	0.100E-03	0.873E+03	0.540E-04	0.143E-03	0.166E+03	0.210E-03	0.355E-03	0.689E+02	0.644E-03	0.899E-03	0.395E+02
TEST 4	0.103E-04	0.292E-03	0.273E+04	0.540E-04	0.292E-03	0.441E+03	0.210E-03	0.553E-03	0.163E+03	0.644E-03	0.115E-02	0.778E+02
TEST 5	0.103E-04	0.166E-04	0.608E+02	0.540E-04	0.594E-04	0.994E+01	0.210E-03	0.213E-03	0.122E+01	0.644E-03	0.644E-03	0.730E-02
TEST 6	0.103E-04	0.450E-04	0.336E+03	0.540E-04	0.964E-04	0.785E+02	0.210E-03	0.274E-03	0.304E+02	0.644E-03	0.717E-03	0.113E+02
TEST 7	0.103E-04	0.142E-04	0.375E+02	0.540E-04	0.111E-03	0.106E+03	0.210E-03	0.498E-03	0.137E+03	0.644E-03	0.159E-02	0.147E+03
TEST 8	0.103E-04	0.912E-05	-.115E+02	0.540E-04	0.436E-04	-.192E+02	0.210E-03	0.171E-03	-.184E+02	0.644E-03	0.532E-03	-.174E+02
TEST 9	0.103E-04	0.119E-04	0.157E+02	0.540E-04	0.490E-04	-.929E+01	0.210E-03	0.164E-03	-.217E+02	0.644E-03	0.480E-03	-.254E+02
TEST 10	0.103E-04	0.107E-04	0.366E+01	0.540E-04	0.596E-04	0.103E+02	0.210E-03	0.242E-03	0.155E+02	0.644E-03	0.765E-03	0.188E+02
TEST 11	0.103E-04	0.124E-04	0.203E+02	0.540E-04	0.608E-04	0.126E+02	0.210E-03	0.216E-03	0.295E+01	0.644E-03	0.644E-03	-.241E-01
TEST 12	0.103E-04	0.882E-05	-.144E+02	0.540E-04	0.317E-04	-.413E+02	0.210E-03	0.109E-03	-.482E+02	0.644E-03	0.320E-03	-.504E+02
TEST 13	0.103E-04	0.114E-04	0.111E+02	0.540E-04	0.654E-04	0.210E+02	0.210E-03	0.260E-03	0.239E+02	0.644E-03	0.807E-03	0.253E+02
TEST 14	0.103E-04	0.129E-04	0.257E+02	0.540E-04	0.562E-04	0.401E+01	0.210E-03	0.204E-03	-.292E+01	0.644E-03	0.615E-03	-.443E+01
TEST 15	0.103E-04	0.767E-05	-.255E+02	0.540E-04	0.499E-04	-.757E+01	0.210E-03	0.210E-03	-.123E+00	0.644E-03	0.662E-03	0.276E+01
TEST 16	0.103E-04	0.126E-04	0.226E+02	0.540E-04	0.665E-04	0.231E+02	0.210E-03	0.258E-03	0.226E+02	0.644E-03	0.782E-03	0.215E+02
TEST 17	0.103E-04	0.890E-05	-.136E+02	0.540E-04	0.497E-04	-.792E+01	0.210E-03	0.201E-03	-.440E+01	0.644E-03	0.629E-03	-.236E+01
TEST 18	0.103E-04	0.111E-04	0.742E+01	0.540E-04	0.676E-04	0.252E+02	0.210E-03	0.278E-03	0.322E+02	0.644E-03	0.871E-03	0.353E+02
TEST 19	0.103E-04	0.615E-05	-.403E+02	0.540E-04	[illegible]	-.352E+02	0.210E-03	0.116E-03	-.436E+02	0.644E-03	0.347E-03	-.461E+02

C-B-6

TEST 20	0.103E-04	0.126E-04	0.223E+02	0.540E-04	0.631E-04	0.168E+02	0.210E-03	0.246E-03	0.171E+02	0.644E-03	0.747E-03	0.161E+02
TEST 21	0.103E-04	0.865E-05	-.160E+02	0.540E-04	0.378E-04	-.302E+02	0.210E-03	0.128E-03	-.392E+02	0.644E-03	0.368E-03	-.429E+02
TEST 22	0.103E-04	0.538E-05	-.419E+02	0.540E-04	0.347E-04	-.357E+02	0.210E-03	0.145E-03	-.310E+02	0.644E-03	0.462E-03	-.282E+02
TEST 23	0.103E-04	0.138E-04	0.338E+02	0.540E-04	0.522E-04	-.337E+01	0.210E-03	0.161E-03	-.235E+02	0.644E-03	0.455E-03	-.293E+02
TEST 24	0.103E-04	0.768E-05	-.254E+02	0.540E-04	0.213E-04	-.605E+02	0.210E-03	0.740E-04	-.648E+02	0.644E-03	0.220E-03	-.658E+02
TEST 25	0.103E-04	0.207E-04	0.101E+03	0.540E-04	0.686E-04	0.271E+02	0.210E-03	0.233E-03	0.111E+02	0.644E-03	0.681E-03	0.579E+01
TEST 26	0.103E-04	0.300E-04	0.269E+03	0.540E-04	0.866E-04	0.605E+02	0.210E-03	0.247E-03	0.176E+02	0.644E-03	0.707E-03	0.979E+01
TEST 27	0.103E-04	0.453E-04	0.339E+03	0.540E-04	0.933E-04	0.728E+02	0.210E-03	0.261E-03	0.243E+02	0.644E-03	0.740E-03	0.150E+02
TEST 28	0.103E-04	0.390E-04	0.286E+03	0.540E-04	0.651E-04	0.205E+02	0.210E-03	0.223E-03	0.632E+01	0.644E-03	0.708E-03	0.994E+01
TEST 29	0.103E-04	0.783E-04	0.660E+03	0.540E-04	0.120E-03	0.137E+03	0.210E-03	0.327E-03	0.558E+02	0.644E-03	0.849E-03	0.318E+02
TEST 30	0.103E-04	0.971E-04	0.843E+03	0.540E-04	0.139E-03	0.157E+03	0.210E-03	0.336E-03	0.598E+02	0.644E-03	0.881E-03	0.368E+02
TEST 31	0.103E-04	0.234E-03	0.217E+04	0.540E-04	0.234E-03	0.333E+03	0.210E-03	0.538E-03	0.156E+03	0.644E-03	0.117E-02	0.822E+02
TEST 32	0.103E-04	0.832E-03	0.790E+04	0.540E-04	0.100E-02	0.191E+04	0.210E-03	0.112E-02	0.434E+03	0.644E-03	0.209E-02	0.225E+03
TEST 33	0.103E-04	0.102E-02	0.981E+04	0.540E-04	0.153E-02	0.273E+04	0.210E-03	0.130E-02	0.521E+03	0.644E-03	0.247E-02	0.283E+03

Beryllium

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE			200 m			500 m			1000 m		
	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.760E-05	0.231E-02	0.303E+05	0.398E-04	0.277E-01	0.634E+05	0.155E-03	0.231E-02	0.139E+04	0.475E-03	0.329E-02	0.594E+03
TEST 2	0.760E-05	0.642E-02	0.843E+05	0.398E-04	0.785E+01	0.197E+08	0.155E-03	0.119E-01	0.760E+04	0.475E-03	0.642E-02	0.125E+04
TEST 3	0.760E-05	0.738E-04	0.871E+03	0.398E-04	0.106E-03	0.166E+03	0.155E-03	0.261E-03	0.686E+02	0.475E-03	0.662E-03	0.394E+02
TEST 4	0.760E-05	0.215E-03	0.273E+04	0.398E-04	0.215E-03	0.441E+03	0.155E-03	0.407E-03	0.163E+03	0.475E-03	0.844E-03	0.776E+02
TEST 5	0.760E-05	0.122E-04	0.606E+02	0.398E-04	0.437E-04	0.991E+01	0.155E-03	0.157E-03	0.105E+01	0.475E-03	0.475E-03	-.924E-01
TEST 6	0.760E-05	0.331E-04	0.336E+03	0.398E-04	0.710E-04	0.784E+02	0.155E-03	0.202E-03	0.302E+02	0.475E-03	0.528E-03	0.112E+02
TEST 7	0.760E-05	0.104E-04	0.373E+02	0.398E-04	0.821E-04	0.106E+03	0.155E-03	0.367E-03	0.137E+03	0.475E-03	0.117E-02	0.146E+03
TEST 8	0.760E-05	0.672E-05	-.116E+02	0.398E-04	0.322E-04	-.192E+02	0.155E-03	0.126E-03	-.186E+02	0.475E-03	0.392E-03	-.175E+02
TEST 9	0.760E-05	0.878E-05	0.155E+02	0.398E-04	0.361E-04	-.932E+01	0.155E-03	0.121E-03	-.218E+02	0.475E-03	0.354E-03	-.255E+02
TEST 10	0.760E-05	0.787E-05	0.352E+01	0.398E-04	0.439E-04	0.103E+02	0.155E-03	0.179E-03	0.153E+02	0.475E-03	0.564E-03	0.186E+02
TEST 11	0.760E-05	0.913E-05	0.201E+02	0.398E-04	0.448E-04	0.126E+02	0.155E-03	0.159E-03	0.278E+01	0.475E-03	0.474E-03	-.124E+00
TEST 12	0.760E-05	0.650E-05	-.145E+02	0.398E-04	0.233E-04	-.414E+02	0.155E-03	0.802E-04	-.482E+02	0.475E-03	0.235E-03	-.504E+02
TEST 13	0.760E-05	0.843E-05	0.110E+02	0.398E-04	0.482E-04	0.210E+02	0.155E-03	0.192E-03	0.237E+02	0.475E-03	0.595E-03	0.252E+02
TEST 14	0.760E-05	0.954E-05	0.255E+02	0.398E-04	0.414E-04	0.398E+01	0.155E-03	0.150E-03	-.329E+01	0.475E-03	0.454E-03	-.452E+01
TEST 15	0.760E-05	0.565E-05	-.256E+02	0.398E-04	0.368E-04	-.759E+01	0.155E-03	0.155E-03	-.293E+00	0.475E-03	0.488E-03	0.266E+01
TEST 16	0.760E-05	0.930E-05	0.224E+02	0.398E-04	0.490E-04	0.231E+02	0.155E-03	0.190E-03	0.226E+02	0.475E-03	0.576E-03	0.213E+02
TEST 17	0.760E-05	0.656E-05	-.137E+02	0.398E-04	0.366E-04	-.795E+01	0.155E-03	0.148E-03	-.456E+01	0.475E-03	0.463E-03	-.246E+01
TEST 18	0.760E-05	0.615E-05	0.727E+01	0.398E-04	0.430E-04	0.252E+02	0.155E-03	0.204E-03	0.319E+02	0.475E-03	0.642E-03	0.352E+02
TEST 19	0.760E-05	[illegible]	[illegible]	0.398E-04	0.258E-04	-.352E+02	0.155E-03	0.873E-04	-.437E+02	0.475E-03	0.256E-03	-.461E+02

TEST 20	0.760E-05	0.920E-05	0.221E+02	0.398E-04	0.465E-04	0.167E+02	0.155E-03	0.181E-03	0.169E+02	0.475E-03	0.551E-03	0.160E+02
TEST 21	0.760E-05	0.637E-05	-.161E+02	0.398E-04	0.279E-04	-.300E+02	0.155E-03	0.940E-04	-.393E+02	0.475E-03	0.271E-03	-.429E+02
TEST 22	0.760E-05	0.441E-05	-.420E+02	0.398E-04	0.256E-04	-.357E+02	0.155E-03	0.107E-03	-.311E+02	0.475E-03	0.341E-03	-.283E+02
TEST 23	0.760E-05	0.102E-04	0.336E+02	0.398E-04	0.304E-04	-.340E+01	0.155E-03	0.118E-03	-.237E+02	0.475E-03	0.336E-03	-.294E+02
TEST 24	0.760E-05	0.566E-05	-.255E+02	0.398E-04	0.157E-04	-.605E+02	0.155E-03	0.545E-04	-.640E+02	0.475E-03	0.162E-03	-.659E+02
TEST 25	0.760E-05	0.153E-04	0.101E+03	0.398E-04	0.506E-04	0.271E+02	0.155E-03	0.172E-03	0.109E+02	0.475E-03	0.502E-03	0.568E+01
TEST 26	0.760E-05	0.280E-04	0.260E+03	0.398E-04	0.630E-04	0.604E+02	0.155E-03	0.182E-03	0.174E+02	0.475E-03	0.521E-03	0.969E+01
TEST 27	0.760E-05	0.334E-04	0.339E+03	0.398E-04	0.680E-04	0.728E+02	0.155E-03	0.192E-03	0.240E+02	0.475E-03	0.546E-03	0.148E+02
TEST 28	0.760E-05	0.293E-04	0.286E+03	0.398E-04	0.480E-04	0.205E+02	0.155E-03	0.165E-03	0.613E+01	0.475E-03	0.522E-03	0.983E+01
TEST 29	0.760E-05	0.577E-04	0.659E+03	0.398E-04	0.945E-04	0.137E+03	0.155E-03	0.241E-03	0.555E+02	0.475E-03	0.625E-03	0.317E+02
TEST 30	0.760E-05	0.716E-04	0.842E+03	0.398E-04	0.102E-03	0.157E+03	0.155E-03	0.247E-03	0.595E+02	0.475E-03	0.649E-03	0.367E+02
TEST 31	0.760E-05	0.172E-03	0.217E+04	0.398E-04	0.172E-03	0.333E+03	0.155E-03	0.396E-03	0.156E+03	0.475E-03	0.864E-03	0.820E+02
TEST 32	0.760E-05	0.613E-03	0.797E+04	0.398E-04	0.793E-03	0.191E+04	0.155E-03	0.827E-03	0.433E+03	0.475E-03	0.154E-02	0.225E+03
TEST 33	0.760E-05	0.752E-03	0.980E+04	0.398E-04	0.113E-02	0.273E+04	0.155E-03	0.961E-03	0.520E+03	0.475E-03	0.182E-02	0.283E+03

Bis(2 ..., Hexyl) , late

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

	MAXIMUM DISTANCE			200 m			500 m			1000 m		
CASE NO.	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.449E-02	0.136E+01	0.303E+05	0.235E-01	0.163E+02	0.694E+05	0.914E-01	0.136E+01	0.139E+04	0.280E+00	0.195E+01	0.595E+03
TEST 2	0.449E-02	0.379E+01	0.843E+05	0.235E-01	0.464E+04	0.197E+08	0.914E-01	0.704E+01	0.761E+04	0.280E+00	0.379E+01	0.125E+04
TEST 3	0.449E-02	0.436E-01	0.871E+03	0.235E-01	0.624E-01	0.166E+03	0.914E-01	0.154E+00	0.688E+02	0.280E+00	0.391E+00	0.396E+02
TEST 4	0.449E-02	0.127E+00	0.273E+04	0.235E-01	0.127E+00	0.441E+03	0.914E-01	0.240E+00	0.163E+03	0.280E+00	0.498E+00	0.779E+02
TEST 5	0.449E-02	0.721E-02	0.605E+02	0.235E-01	0.258E-01	0.991E+01	0.914E-01	0.925E-01	0.118E+01	0.280E+00	0.280E+00	0.775E-01
TEST 6	0.449E-02	0.196E-01	0.336E+03	0.235E-01	0.419E-01	0.784E+02	0.914E-01	0.119E+00	0.302E+02	0.280E+00	0.312E+00	0.114E+02
TEST 7	0.449E-02	0.616E-02	0.372E+02	0.235E-01	0.465E-01	0.106E+03	0.914E-01	0.217E+00	0.137E+03	0.280E+00	0.691E+00	0.147E+03
TEST 8	0.449E-02	0.397E-02	-.116E+02	0.235E-01	0.190E-01	-.192E+02	0.914E-01	0.745E-01	-.185E+02	0.280E+00	0.231E+00	-.174E+02
TEST 9	0.449E-02	0.518E-02	0.155E+02	0.235E-01	0.213E-01	-.931E+01	0.914E-01	0.715E-01	-.217E+02	0.280E+00	0.209E+00	-.254E+02
TEST 10	0.449E-02	0.465E-02	0.347E+01	0.235E-01	0.259E-01	0.103E+02	0.914E-01	0.106E+00	0.154E+02	0.280E+00	0.333E+00	0.189E+02
TEST 11	0.449E-02	0.539E-02	0.201E+02	0.235E-01	0.265E-01	0.126E+02	0.914E-01	0.941E-01	0.292E+01	0.280E+00	0.280E+00	0.461E-01
TEST 12	0.449E-02	0.384E-02	-.145E+02	0.235E-01	0.138E-01	-.413E+02	0.914E-01	0.474E-01	-.482E+02	0.280E+00	0.139E+00	-.504E+02
TEST 13	0.449E-02	0.498E-02	0.109E+02	0.235E-01	0.284E-01	0.210E+02	0.914E-01	0.113E+00	0.238E+02	0.280E+00	0.351E+00	0.254E+02
TEST 14	0.449E-02	0.563E-02	0.255E+02	0.235E-01	0.244E-01	0.399E+01	0.914E-01	0.887E-01	-.295E+01	0.280E+00	0.268E+00	-.436E+01
TEST 15	0.449E-02	0.334E-02	-.256E+02	0.235E-01	0.217E-01	-.759E+01	0.914E-01	0.913E-01	-.158E+00	0.280E+00	0.288E+00	0.283E+01
TEST 16	0.449E-02	0.549E-02	0.223E+02	0.235E-01	0.289E-01	0.231E+02	0.914E-01	0.112E+00	0.228E+02	0.280E+00	0.340E+00	0.215E+02
TEST 17	0.449E-02	0.387E-02	-.137E+02	0.235E-01	0.216E-01	-.794E+01	0.914E-01	0.873E-01	-.443E+01	0.280E+00	0.274E+00	-.229E+01
TEST 18	0.449E-02	0.481E-02	0.721E+01	0.235E-01	0.294E-01	0.252E+02	0.914E-01	0.121E+00	0.321E+02	0.280E+00	0.379E+00	0.354E+02
TEST [illegible]	0.449E-02	0.268E-02	-.404E+02	0.235E-01	0.152E-01	-.352E+02	0.914E-01	0.515E-01	-.436E+02	0.280E+00	0.151E+00	-.460E+02

TEST 20	0.449E-02	0.540E-02	0.220E+02	0.235E-01	0.274E-01	0.167E+02	0.914E-01	0.107E+00	0.171E+02	0.280E+00	0.325E+00	0.162E+02
TEST 21	0.449E-02	0.376E-02	-.162E+02	0.235E-01	0.164E-01	-.300E+02	0.914E-01	0.555E-01	-.392E+02	0.280E+00	0.160E+00	-.420E+02
TEST 22	0.449E-02	0.260E-02	-.421E+02	0.235E-01	0.151E-01	-.357E+02	0.914E-01	0.631E-01	-.310E+02	0.280E+00	0.201E+00	-.281E+02
TEST 23	0.449E-02	0.599E-02	0.335E+02	0.235E-01	0.227E-01	-.339E+01	0.914E-01	0.699E-01	-.236E+02	0.280E+00	0.198E+00	-.292E+02
TEST 24	0.449E-02	0.334E-02	-.255E+02	0.235E-01	0.927E-02	-.605E+02	0.914E-01	0.322E-01	-.648E+02	0.280E+00	0.958E-01	-.658E+02
TEST 25	0.449E-02	0.902E-02	0.101E+03	0.235E-01	0.299E-01	0.271E+02	0.914E-01	0.102E+00	0.111E+02	0.280E+00	0.296E+00	0.586E+01
TEST 26	0.449E-02	0.165E-01	0.260E+03	0.235E-01	0.377E-01	0.604E+02	0.914E-01	0.107E+00	0.175E+02	0.280E+00	0.308E+00	0.987E+01
TEST 27	0.449E-02	0.197E-01	0.339E+03	0.235E-01	0.406E-01	0.728E+02	0.914E-01	0.114E+00	0.242E+02	0.280E+00	0.322E+00	0.150E+02
TEST 28	0.449E-02	0.173E-01	0.286E+03	0.235E-01	0.283E-01	0.205E+02	0.914E-01	0.971E-01	0.628E+01	0.280E+00	0.300E+00	0.100E+02
TEST 29	0.449E-02	0.341E-01	0.650E+03	0.235E-01	0.558E-01	0.137E+03	0.914E-01	0.142E+00	0.557E+02	0.280E+00	0.369E+00	0.319E+02
TEST 30	0.449E-02	0.423E-01	0.841E+03	0.235E-01	0.604E-01	0.157E+03	0.914E-01	0.146E+00	0.597E+02	0.280E+00	0.383E+00	0.369E+02
TEST 31	0.449E-02	0.102E+00	0.217E+04	0.235E-01	0.102E+00	0.333E+03	0.914E-01	0.234E+00	0.156E+03	0.280E+00	0.510E+00	0.823E+02
TEST 32	0.449E-02	0.362E+00	0.796E+04	0.235E-01	0.472E+00	0.191E+04	0.914E-01	0.488E+00	0.434E+03	0.280E+00	0.911E+00	0.225E+03
TEST 33	0.449E-02	0.444E+00	0.979E+04	0.235E-01	0.666E+00	0.273E+04	0.914E-01	0.567E+00	0.521E+03	0.280E+00	0.107E+01	0.283E+03

Cadmium

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

	MAXIMUM DISTANCE			200 m			500 m			1000 m		
CASE NO.	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.103E-04	0.313E-02	0.303E+05	0.540E-04	0.375E-01	0.694E+05	0.210E-03	0.313E-02	0.139E+04	0.644E-03	0.447E-02	0.594E+03
TEST 2	0.103E-04	0.871E-02	0.845E+05	0.540E-04	0.107E+02	0.197E+08	0.210E-03	0.162E-01	0.761E+04	0.644E-03	0.871E-02	0.125E+04
TEST 3	0.103E-04	0.100E-03	0.873E+03	0.540E-04	0.143E-03	0.166E+03	0.210E-03	0.355E-03	0.689E+02	0.644E-03	0.899E-03	0.395E+02
TEST 4	0.103E-04	0.292E-03	0.273E+04	0.540E-04	0.292E-03	0.441E+03	0.210E-03	0.553E-03	0.163E+03	0.644E-03	0.115E-02	0.778E+02
TEST 5	0.103E-04	0.166E-04	0.608E+02	0.540E-04	0.594E-04	0.994E+01	0.210E-03	0.213E-03	0.122E+01	0.644E-03	0.644E-03	0.730E-02
TEST 6	0.103E-04	0.450E-04	0.336E+03	0.540E-04	0.964E-04	0.785E+02	0.210E-03	0.274E-03	0.304E+02	0.644E-03	0.717E-03	0.113E+02
TEST 7	0.103E-04	0.142E-04	0.375E+02	0.540E-04	0.111E-03	0.106E+03	0.210E-03	0.498E-03	0.137E+03	0.644E-03	0.159E-02	0.147E+03
TEST 8	0.103E-04	0.912E-05	-.115E+02	0.540E-04	0.436E-04	-.192E+02	0.210E-03	0.171E-03	-.184E+02	0.644E-03	0.532E-03	-.174E+02
TEST 9	0.103E-04	0.119E-04	0.157E+02	0.540E-04	0.490E-04	-.929E+01	0.210E-03	0.164E-03	-.217E+02	0.644E-03	0.480E-03	-.254E+02
TEST 10	0.103E-04	0.107E-04	0.366E+01	0.540E-04	0.596E-04	0.103E+02	0.210E-03	0.242E-03	0.155E+02	0.644E-03	0.765E-03	0.188E+02
TEST 11	0.103E-04	0.124E-04	0.203E+02	0.540E-04	0.608E-04	0.126E+02	0.210E-03	0.216E-03	0.295E+01	0.644E-03	0.644E-03	-.241E-01
TEST 12	0.103E-04	0.882E-05	-.144E+02	0.540E-04	0.317E-04	-.413E+02	0.210E-03	0.109E-03	-.482E+02	0.644E-03	0.320E-03	-.504E+02
TEST 13	0.103E-04	0.114E-04	0.111E+02	0.540E-04	0.654E-04	0.210E+02	0.210E-03	0.260E-03	0.239E+02	0.644E-03	0.807E-03	0.253E+02
TEST 14	0.103E-04	0.129E-04	0.257E+02	0.540E-04	0.562E-04	0.401E+01	0.210E-03	0.204E-03	-.292E+01	0.644E-03	0.615E-03	-.443E+01
TEST 15	0.103E-04	0.767E-05	-.255E+02	0.540E-04	0.499E-04	-.757E+01	0.210E-03	0.210E-03	-.123E+00	0.644E-03	0.662E-03	0.276E+01
TEST 16	0.103E-04	0.126E-04	0.226E+02	0.540E-04	0.665E-04	0.231E+02	0.210E-03	0.258E-03	0.229E+02	0.644E-03	0.782E-03	0.215E+02
TEST 17	0.103E-04	0.830E-05	-.136E+02	0.540E-04	0.497E-04	-.792E+01	0.210E-03	0.201E-03	-.440E+01	0.644E-03	0.629E-03	-.236E+01
TEST 18	0.103E-04	0.111E-04	[illegible]	0.540E-04	0.676E-04	0.252E+02	0.210E-03	0.278E-03	0.322E+02	0.644E-03	0.871E-03	0.353E+02
TEST 19	[illegible]	0.615E-05	-.403E+02	0.540E-04	[illegible]	-.352E+02	[illegible]	0.118E-03	-.436E+02	0.644E-03	0.347E-03	-.461E+02

Reproduced from best available copy.

TEST 20	0.103E-04	0.126E-04	0.223E+02	0.540E-04	0.631E-04	0.166E+02	0.210E-03	0.246E-03	0.171E+02	0.644E-03	0.747E-03	0.161E+02
TEST 21	0.103E-04	0.865E-05	-.160E+02	0.540E-04	0.378E-04	-.300E+02	0.210E-03	0.128E-03	-.392E+02	0.644E-03	0.368E-03	-.429E+02
TEST 22	0.103E-04	0.598E-05	-.419E+02	0.540E-04	0.347E-04	-.357E+02	0.210E-03	0.145E-03	-.310E+02	0.644E-03	0.462E-03	-.282E+02
TEST 23	0.103E-04	0.130E-04	0.330E+02	0.540E-04	0.522E-04	-.337E+01	0.210E-03	0.161E-03	-.235E+02	0.644E-03	0.455E-03	-.293E+02
TEST 24	0.103E-04	0.768E-05	-.254E+02	0.540E-04	0.213E-04	-.605E+02	0.210E-03	0.740E-04	-.648E+02	0.644E-03	0.220E-03	-.658E+02
TEST 25	0.103E-04	0.207E-04	0.101E+03	0.540E-04	0.606E-04	0.271E+02	0.210E-03	0.233E-03	0.111E+02	0.644E-03	0.681E-03	0.579E+01
TEST 26	0.103E-04	0.380E-04	0.269E+03	0.540E-04	0.866E-04	0.605E+02	0.210E-03	0.247E-03	0.176E+02	0.644E-03	0.707E-03	0.979E+01
TEST 27	0.103E-04	0.453E-04	0.339E+03	0.540E-04	0.933E-04	0.728E+02	0.210E-03	0.261E-03	0.243E+02	0.644E-03	0.740E-03	0.150E+02
TEST 28	0.103E-04	0.338E-04	0.286E+03	0.540E-04	0.651E-04	0.205E+02	0.210E-03	0.223E-03	0.632E+01	0.644E-03	0.708E-03	0.994E+01
TEST 29	0.103E-04	0.783E-04	0.660E+03	0.540E-04	0.120E-03	0.137E+03	0.210E-03	0.327E-03	0.558E+02	0.644E-03	0.849E-03	0.310E+02
TEST 30	0.103E-04	0.971E-04	0.843E+03	0.540E-04	0.139E-03	0.157E+03	0.210E-03	0.336E-03	0.598E+02	0.644E-03	0.881E-03	0.368E+02
TEST 31	0.103E-04	0.234E-03	0.217E+04	0.540E-04	0.234E-03	0.333E+03	0.210E-03	0.538E-03	0.156E+03	0.644E-03	0.117E-02	0.822E+02
TEST 32	0.103E-04	0.832E-03	0.798E+04	0.540E-04	0.108E-02	0.191E+04	0.210E-03	0.112E-02	0.434E+03	0.644E-03	0.209E-02	0.225E+03
TEST 33	0.103E-04	0.102E-02	0.981E+04	0.540E-04	0.153E-02	0.273E+04	0.210E-03	0.130E-02	0.521E+03	0.644E-03	0.247E-02	0.283E+03

Carbon tet.

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE BASE ALLOW RATE	ALLOW RATE	% DIFF	200 m BASE ALLOW RATE	ALLOW RATE	% DIFF	500 m BASE ALLOW RATE	ALLOW RATE	% DIFF	1000 m BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.488E-03	0.140E+00	0.323E+05	0.256E-02	0.178E+01	0.693E+05	0.995E-02	0.148E+00	0.139E+04	0.305E-01	0.212E+00	0.594E+03
TEST 2	0.488E-03	0.413E+00	0.844E+05	0.256E-02	0.505E+03	0.197E+08	0.995E-02	0.767E+00	0.761E+04	0.305E-01	0.413E+00	0.125E+04
TEST 3	0.488E-03	0.475E-02	0.872E+03	0.256E-02	0.679E-02	0.165E+03	0.995E-02	0.168E-01	0.689E+02	0.305E-01	0.426E-01	0.396E+02
TEST 4	0.488E-03	0.138E-01	0.273E+04	0.256E-02	0.138E-01	0.440E+03	0.995E-02	0.262E-01	0.163E+03	0.305E-01	0.542E-01	0.779E+02
TEST 5	0.488E-03	0.784E-03	0.607E+02	0.256E-02	0.281E-02	0.985E+01	0.995E-02	0.101E-01	0.119E+01	0.305E-01	0.305E-01	0.246E-01
TEST 6	0.488E-03	0.213E-02	0.336E+03	0.256E-02	0.457E-02	0.783E+02	0.995E-02	0.130E-01	0.304E+02	0.305E-01	0.340E-01	0.113E+02
TEST 7	0.488E-03	0.671E-03	0.375E+02	0.256E-02	0.526E-02	0.106E+03	0.995E-02	0.236E-01	0.137E+03	0.305E-01	0.753E-01	0.147E+03
TEST 8	0.488E-03	0.432E-03	-.115E+02	0.256E-02	0.207E-02	-.193E+02	0.995E-02	0.811E-02	-.185E+02	0.305E-01	0.252E-01	-.174E+02
TEST 9	0.488E-03	0.564E-03	0.157E+02	0.256E-02	0.232E-02	-.937E+01	0.995E-02	0.779E-02	-.217E+02	0.305E-01	0.228E-01	-.254E+02
TEST 10	0.488E-03	0.505E-03	0.354E+01	0.256E-02	0.282E-02	0.102E+02	0.995E-02	0.115E-01	0.154E+02	0.305E-01	0.362E-01	0.188E+02
TEST 11	0.488E-03	0.587E-03	0.203E+02	0.256E-02	0.288E-02	0.125E+02	0.995E-02	0.102E-01	0.292E+01	0.305E-01	0.305E-01	-.678E-02
TEST 12	0.488E-03	0.418E-03	-.144E+02	0.256E-02	0.150E-02	-.414E+02	0.995E-02	0.516E-02	-.482E+02	0.305E-01	0.151E-01	-.504E+02
TEST 13	0.488E-03	0.542E-03	0.111E+02	0.256E-02	0.310E-02	0.209E+02	0.995E-02	0.123E-01	0.238E+02	0.305E-01	0.382E-01	0.254E+02
TEST 14	0.488E-03	0.613E-03	0.257E+02	0.256E-02	0.266E-02	0.391E+01	0.995E-02	0.966E-02	-.294E+01	0.305E-01	0.292E-01	-.441E+01
TEST 15	0.488E-03	0.363E-03	-.255E+02	0.256E-02	0.236E-02	-.764E+01	0.995E-02	0.994E-02	-.150E+00	0.305E-01	0.313E-01	0.270E+01
TEST 16	0.488E-03	0.598E-03	0.225E+02	0.256E-02	0.315E-02	0.230E+02	0.995E-02	0.122E-01	0.226E+02	0.305E-01	0.370E-01	0.215E+02
TEST 17	0.488E-03	0.422E-03	-.136E+02	0.256E-02	0.236E-02	-.80[illegible]E+01	0.995E-02	0.951E-02	-.443E+01	0.305E-01	0.298E-01	-.234E+01
TEST 18	0.488E-03	0.524E-03	0.739E+01	0.256E-02	0.320E-02	0.251E+02	0.995E-02	0.131E-01	0.321E+02	0.305E-01	0.413E-01	0.353E+02
TEST 19	0.488E-03	[illegible]	[illegible]	0.256E-02	[illegible]	-.350E+02	0.995E-02	0.561E-02	-.436E+02	0.305E-01	0.165E-01	-.461E+02

Reproduced from best available copy.

C-B-14

TEST 20	0.400E-03	0.596E-03	0.222E+02	0.256E-02	0.299E-02	0.167E+02	0.995E-02	0.116E-01	0.171E+02	0.305E-01	0.354E-01	0.161E+02
TEST 21	0.400E-03	0.410E-03	-.161E+02	0.256E-02	0.179E-02	-.301E+02	0.995E-02	0.605E-02	-.392E+02	0.305E-01	0.174E-01	-.429E+02
TEST 22	0.400E-03	0.283E-03	-.420E+02	0.256E-02	0.164E-02	-.358E+02	0.995E-02	0.687E-02	-.310E+02	0.305E-01	0.219E-01	-.282E+02
TEST 23	0.400E-03	0.653E-03	0.337E+02	0.256E-02	0.247E-02	-.345E+01	0.995E-02	0.760E-02	-.236E+02	0.305E-01	0.216E-01	-.293E+02
TEST 24	0.400E-03	0.364E-03	-.254E+02	0.256E-02	0.101E-02	-.606E+02	0.995E-02	0.350E-02	-.640E+02	0.305E-01	0.104E-01	-.658E+02
TEST 25	0.400E-03	0.982E-03	0.101E+03	0.256E-02	0.325E-02	0.270E+02	0.995E-02	0.111E-01	0.111E+02	0.305E-01	0.323E-01	0.581E+01
TEST 26	0.400E-03	0.100E-02	0.260E+03	0.256E-02	0.410E-02	0.603E+02	0.995E-02	0.117E-01	0.175E+02	0.305E-01	0.335E-01	0.981E+01
TEST 27	0.400E-03	0.214E-02	0.339E+03	0.256E-02	0.442E-02	0.727E+02	0.995E-02	0.124E-01	0.242E+02	0.305E-01	0.351E-01	0.150E+02
TEST 28	0.400E-03	0.100E-02	0.286E+03	0.256E-02	0.308E-02	0.204E+02	0.995E-02	0.106E-01	0.629E+01	0.305E-01	0.335E-01	0.996E+01
TEST 29	0.400E-03	0.371E-02	0.660E+03	0.256E-02	0.607E-02	0.137E+03	0.995E-02	0.155E-01	0.557E+02	0.305E-01	0.402E-01	0.318E+02
TEST 30	0.400E-03	0.460E-02	0.843E+03	0.256E-02	0.658E-02	0.157E+03	0.995E-02	0.159E-01	0.597E+02	0.305E-01	0.417E-01	0.368E+02
TEST 31	0.400E-03	0.111E-01	0.217E+04	0.256E-02	0.111E-01	0.333E+03	0.995E-02	0.255E-01	0.156E+03	0.305E-01	0.556E-01	0.822E+02
TEST 32	0.400E-03	0.394E-01	0.798E+04	0.256E-02	0.514E-01	0.191E+04	0.995E-02	0.532E-01	0.434E+03	0.305E-01	0.992E-01	0.225E+03
TEST 33	0.400E-03	0.404E-01	0.981E+04	0.256E-02	0.725E-01	0.273E+04	0.995E-02	0.617E-01	0.521E+03	0.305E-01	0.117E+00	0.283E+03

C-6.15

Chromium

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE			200 m			500 m			1000 m		
	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.163E-05	0.495E-03	0.302E+05	0.852E-05	0.593E-02	0.694E+05	0.332E-04	0.495E-03	0.139E+04	0.102E-03	0.706E-03	0.592E+03
TEST 2	0.163E-05	0.138E-02	0.843E+05	0.852E-05	0.168E+01	0.197E+08	0.332E-04	0.256E-02	0.760E+04	0.102E-03	0.138E-02	0.125E+04
TEST 3	0.163E-05	0.158E-04	0.870E+03	0.852E-05	0.226E-04	0.166E+03	0.332E-04	0.560E-04	0.687E+02	0.102E-03	0.142E-03	0.391E+02
TEST 4	0.163E-05	0.461E-04	0.273E+04	0.852E-05	0.461E-04	0.441E+03	0.332E-04	0.873E-04	0.163E+03	0.102E-03	0.181E-03	0.773E+02
TEST 5	0.163E-05	0.261E-05	0.604E+02	0.852E-05	0.937E-05	0.100E+02	0.332E-04	0.336E-04	0.109E+01	0.102E-03	0.102E-03	-.302E+00
TEST 6	0.163E-05	0.710E-05	0.335E+03	0.852E-05	0.152E-04	0.786E+02	0.332E-04	0.432E-04	0.301E+02	0.102E-03	0.113E-03	0.110E+02
TEST 7	0.163E-05	0.224E-05	0.372E+02	0.852E-05	0.176E-04	0.107E+03	0.332E-04	0.787E-04	0.137E+03	0.102E-03	0.251E-03	0.146E+03
TEST 8	0.163E-05	0.144E-05	-.117E+02	0.852E-05	0.689E-05	-.191E+02	0.332E-04	0.270E-04	-.185E+02	0.102E-03	0.839E-04	-.177E+02
TEST 9	0.163E-05	0.188E-05	0.154E+02	0.852E-05	0.773E-05	-.923E+01	0.332E-04	0.260E-04	-.218E+02	0.102E-03	0.758E-04	-.256E+02
TEST 10	0.163E-05	0.169E-05	0.343E+01	0.852E-05	0.940E-05	0.104E+02	0.332E-04	0.383E-04	0.153E+02	0.102E-03	0.121E-03	0.184E+02
TEST 11	0.163E-05	0.196E-05	0.200E+02	0.852E-05	0.960E-05	0.127E+02	0.332E-04	0.341E-04	0.282E+01	0.102E-03	0.102E-03	-.334E+00
TEST 12	0.163E-05	0.139E-05	-.146E+02	0.852E-05	0.500E-05	-.413E+02	0.332E-04	0.172E-04	-.482E+02	0.102E-03	0.504E-04	-.505E+02
TEST 13	0.163E-05	0.181E-05	0.109E+02	0.852E-05	0.103E-04	0.211E+02	0.332E-04	0.411E-04	0.237E+02	0.102E-03	0.127E-03	0.250E+02
TEST 14	0.163E-05	0.204E-05	0.254E+02	0.852E-05	0.887E-05	0.409E+01	0.332E-04	0.322E-04	-.304E+01	0.102E-03	0.972E-04	-.472E+01
TEST 15	0.163E-05	0.121E-05	-.257E+02	0.852E-05	0.788E-05	-.750E+01	0.332E-04	0.331E-04	-.250E+00	0.102E-03	0.104E-03	0.244E+01
TEST 16	0.163E-05	0.199E-05	0.223E+02	0.852E-05	0.105E-04	0.232E+02	0.332E-04	0.407E-04	0.227E+02	0.102E-03	0.123E-03	0.211E+02
TEST 17	0.163E-05	0.141E-05	-.136E+02	0.852E-05	0.785E-05	-.785E+01	0.332E-04	0.317E-04	-.452E+01	0.102E-03	0.993E-04	-.266E+01
TEST 18	0.163E-05	0.175E-05	0.717E+01	0.852E-05	0.107E-04	0.253E+02	0.332E-04	0.436E-04	0.320E+02	0.102E-03	0.139E-03	0.349E+02
TEST 19	0.163E-05	0.971E-06	-.404E+02	0.852E-05	0.553E-05	-.351E+02	0.332E-04	0.187E-04	-.437E+02	0.102E-03	0.548E-04	-.462E+02

TEST 20	0.163E-05	0.199E-05	0.220E+02	0.852E-05	0.996E-05	0.168E+02	0.332E-04	0.388E-04	0.169E+02	0.102E-03	0.110E-03	0.157E+02
TEST 21	0.163E-05	0.137E-05	-.162E+02	0.852E-05	0.597E-05	-.299E+02	0.332E-04	0.202E-04	-.393E+02	0.102E-03	0.581E-04	-.431E+02
TEST 22	0.163E-05	0.944E-06	-.421E+02	0.852E-05	0.548E-05	-.357E+02	0.332E-04	0.229E-04	-.311E+02	0.102E-03	0.730E-04	-.284E+02
TEST 23	0.163E-05	0.218E-05	0.334E+02	0.852E-05	0.824E-05	-.330E+01	0.332E-04	0.253E-04	-.236E+02	0.102E-03	0.719E-04	-.295E+02
TEST 24	0.163E-05	0.121E-05	-.256E+02	0.852E-05	0.337E-05	-.605E+02	0.332E-04	0.117E-04	-.648E+02	0.102E-03	0.348E-04	-.659E+02
TEST 25	0.163E-05	0.327E-05	0.101E+03	0.852E-05	0.108E-04	0.272E+02	0.332E-04	0.368E-04	0.110E+02	0.102E-03	0.108E-03	0.546E+01
TEST 26	0.163E-05	0.599E-05	0.268E+03	0.852E-05	0.137E-04	0.606E+02	0.332E-04	0.390E-04	0.174E+02	0.102E-03	0.112E-03	0.945E+01
TEST 27	0.163E-05	0.715E-05	0.338E+03	0.852E-05	0.147E-04	0.730E+02	0.332E-04	0.412E-04	0.241E+02	0.102E-03	0.117E-03	0.146E+02
TEST 28	0.163E-05	0.628E-05	0.285E+03	0.852E-05	0.103E-04	0.206E+02	0.332E-04	0.353E-04	0.618E+01	0.102E-03	0.112E-03	0.960E+01
TEST 29	0.163E-05	0.124E-04	0.658E+03	0.852E-05	0.202E-04	0.138E+03	0.332E-04	0.517E-04	0.556E+02	0.102E-03	0.134E-03	0.314E+02
TEST 30	0.163E-05	0.153E-04	0.841E+03	0.852E-05	0.219E-04	0.157E+03	0.332E-04	0.530E-04	0.596E+02	0.102E-03	0.139E-03	0.364E+02
TEST 31	0.163E-05	0.370E-04	0.217E+04	0.852E-05	0.370E-04	0.334E+03	0.332E-04	0.849E-04	0.156E+03	0.102E-03	0.185E-03	0.816E+02
TEST 32	0.163E-05	0.131E-03	0.796E+04	0.852E-05	0.171E-03	0.191E+04	0.332E-04	0.177E-03	0.434E+03	0.102E-03	0.331E-03	0.224E+03
TEST 33	0.163E-05	0.161E-03	0.979E+04	0.852E-05	0.242E-03	0.274E+04	0.332E-04	0.206E-03	0.520E+03	0.102E-03	0.390E-03	0.282E+03

Chloroform

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

	MAXIMUM DISTANCE			200 m			500 m			1000 m		
CASE NO.	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.778E-03	0.236E+00	0.303E+05	0.407E-02	0.283E+01	0.695E+05	0.158E-01	0.236E+00	0.140E+04	0.486E-01	0.337E+00	0.594E+03
TEST 2	0.778E-03	0.657E+00	0.844E+05	0.407E-02	0.804E+03	0.197E+08	0.158E-01	0.122E+01	0.763E+04	0.486E-01	0.657E+00	0.125E+04
TEST 3	0.778E-03	0.756E-02	0.871E+03	0.407E-02	0.108E-01	0.166E+03	0.158E-01	0.268E-01	0.634E+02	0.486E-01	0.678E-01	0.395E+02
TEST 4	0.779E-03	0.220E-01	0.273E+04	0.407E-02	0.220E-01	0.441E+03	0.158E-01	0.417E-01	0.164E+03	0.486E-01	0.864E-01	0.778E+02
TEST 5	0.778E-03	0.125E-02	0.606E+02	0.407E-02	0.448E-02	0.100E+02	0.158E-01	0.160E-01	0.149E+01	0.486E-01	0.486E-01	-.288E-01
TEST 6	0.778E-03	0.339E-02	0.336E+03	0.407E-02	0.727E-02	0.786E+02	0.158E-01	0.207E-01	0.307E+02	0.486E-01	0.541E-01	0.113E+02
TEST 7	0.778E-03	0.107E-02	0.373E+02	0.407E-02	0.841E-02	0.107E+03	0.158E-01	0.376E-01	0.138E+03	0.486E-01	0.120E+00	0.147E+03
TEST 8	0.778E-03	0.688E-03	-.116E+02	0.407E-02	0.329E-02	-.191E+02	0.158E-01	0.129E-01	-.182E+02	0.486E-01	0.401E-01	-.175E+02
TEST 9	0.778E-03	0.899E-03	0.155E+02	0.407E-02	0.370E-02	-.921E+01	0.158E-01	0.124E-01	-.215E+02	0.486E-01	0.362E-01	-.254E+02
TEST 10	0.778E-03	0.805E-03	0.353E+01	0.407E-02	0.449E-02	0.104E+02	0.158E-01	0.183E-01	0.158E+02	0.486E-01	0.577E-01	0.187E+02
TEST 11	0.778E-03	0.935E-03	0.201E+02	0.407E-02	0.459E-02	0.127E+02	0.158E-01	0.163E-01	0.323E+01	0.486E-01	0.486E-01	-.601E-01
TEST 12	0.778E-03	0.665E-03	-.145E+02	0.407E-02	0.239E-02	-.413E+02	0.158E-01	0.821E-02	-.480E+02	0.486E-01	0.241E-01	-.504E+02
TEST 13	0.778E-03	0.863E-03	0.110E+02	0.407E-02	0.493E-02	0.211E+02	0.158E-01	0.196E-01	0.242E+02	0.486E-01	0.609E-01	0.253E+02
TEST 14	0.778E-03	0.977E-03	0.255E+02	0.407E-02	0.424E-02	0.410E+01	0.158E-01	0.154E-01	-.266E+01	0.486E-01	0.464E-01	-.446E+01
TEST 15	0.778E-03	0.579E-03	-.256E+02	0.407E-02	0.377E-02	-.748E+01	0.158E-01	0.158E-01	0.143E+00	0.486E-01	0.499E-01	0.272E+01
TEST 16	0.778E-03	0.952E-03	0.224E+02	0.407E-02	0.502E-02	0.232E+02	0.158E-01	0.195E-01	0.231E+02	0.486E-01	0.590E-01	0.214E+02
TEST 17	0.778E-03	0.672E-03	-.137E+02	0.407E-02	0.375E-02	-.784E+01	0.158E-01	0.151E-01	-.415E+01	0.486E-01	0.474E-01	-.240E+01
TEST 18	0.778E-03	0.635E-03	[illegible]	0.407E-02	0.510E-02	0.253E+02	0.158E-01	0.209E-01	0.325E+02	0.486E-01	0.657E-01	0.353E+02
[illegible]	[illegible]	[illegible]	-.404E+02	0.407E-02	0.264E-02	-.351E+02	0.158E-01	[illegible]	-.434E+02	0.486E-01	0.262E-01	-.461E+02

Reproduced from best available copy.

TEST 20	0.770E-03	0.950E-03	0.221E+02	0.407E-02	0.476E-02	0.163E+02	0.159E-01	0.186E-01	0.174E+02	0.486E-01	0.564E-01	0.160E+02
TEST 21	0.770E-03	0.652E-03	-.161E+02	0.407E-02	0.285E-02	-.299E+02	0.158E-01	0.963E-02	.291E+02	0.486E-01	0.277E-01	-.429E+02
TEST 22	0.770E-03	0.451E-03	-.420E+02	0.407E-02	0.262E-02	-.357E+02	0.158E-01	0.109E-01	-.306E+02	0.486E-01	0.349E-01	-.282E+02
TEST 23	0.770E-03	0.104E-02	0.336E+02	0.407E-02	0.394E-02	-.320E+01	0.158E-01	0.121E-01	-.233E+02	0.486E-01	0.343E-01	-.293E+02
TEST 24	0.770E-03	0.500E-03	-.255E+02	0.407E-02	0.161E-02	-.605E+02	0.158E-01	0.558E-02	-.647E+02	0.486E-01	0.166E-01	-.658E+02
TEST 25	0.770E-03	0.156E-02	0.101E+03	0.407E-02	0.510E-02	0.272E+02	0.158E-01	0.176E-01	0.114E+02	0.486E-01	0.514E-01	0.575E+01
TEST 26	0.770E-03	0.206E-02	0.258E+03	0.407E-02	0.654E-02	0.606E+02	0.158E-01	0.186E-01	0.179E+02	0.486E-01	0.533E-01	0.975E+01
TEST 27	0.770E-03	0.341E-02	0.339E+03	0.407E-02	0.704E-02	0.730E+02	0.158E-01	0.197E-01	0.246E+02	0.486E-01	0.559E-01	0.149E+02
TEST 28	0.770E-03	0.380E-02	0.206E+03	0.407E-02	0.491E-02	0.206E+02	0.158E-01	0.168E-01	0.660E+01	0.486E-01	0.534E-01	0.930E+01
TEST 29	0.770E-03	0.590E-02	0.659E+03	0.407E-02	0.967E-02	0.138E+03	0.158E-01	0.247E-01	0.562E+02	0.486E-01	0.640E-01	0.318E+02
TEST 30	0.770E-03	0.733E-02	0.842E+03	0.407E-02	0.105E-01	0.157E+03	0.158E-01	0.253E-01	0.602E+02	0.486E-01	0.665E-01	0.368E+02
TEST 31	0.770E-03	0.177E-01	0.217E+04	0.407E-02	0.177E-01	0.334E+03	0.158E-01	0.406E-01	0.157E+03	0.486E-01	0.885E-01	0.821E+02
TEST 32	0.770E-03	0.620E-01	0.797E+04	0.407E-02	0.818E-01	0.191E+04	0.158E-01	0.846E-01	0.436E+03	0.486E-01	0.158E+00	0.225E+03
TEST 33	0.770E-03	0.770E-01	0.980E+04	0.407E-02	0.115E+00	0.274E+04	0.158E-01	0.993E-01	0.522E+03	0.486E-01	0.186E+00	0.283E+03

Chlorcare

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE BASE ALLOW RATE	ALLOW RATE	% DIFF	200 m BASE ALLOW RATE	ALLOW RATE	% DIFF	500 m BASE ALLOW RATE	ALLOW RATE	% DIFF	1000 m BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.488E-04	0.148E-01	0.303E+05	0.256E-03	0.178E+00	0.693E+05	0.995E-03	0.148E-01	0.139E+04	0.305E-02	0.212E-01	0.594E+03
TEST 2	0.488E-04	0.413E-01	0.844E+05	0.256E-03	0.505E+02	0.197E+08	0.995E-03	0.767E-01	0.761E+04	0.305E-02	0.413E-01	0.125E+04
TEST 3	0.488E-04	0.475E-03	0.872E+03	0.256E-03	0.679E-03	0.165E+03	0.995E-03	0.168E-02	0.689E+02	0.305E-02	0.426E-02	0.396E+02
TEST 4	0.488E-04	0.138E-02	0.273E+04	0.256E-03	0.138E-02	0.440E+03	0.995E-03	0.262E-02	0.163E+03	0.305E-02	0.542E-02	0.779E+02
TEST 5	0.488E-04	0.784E-04	0.607E+02	0.256E-03	0.281E-03	0.985E+01	0.995E-03	0.101E-02	0.119E+01	0.305E-02	0.305E-02	0.246E-01
TEST 6	0.488E-04	0.213E-03	0.336E+03	0.256E-03	0.457E-03	0.783E+02	0.995E-03	0.130E-02	0.304E+02	0.305E-02	0.340E-02	0.113E+02
TEST 7	0.488E-04	0.671E-04	0.375E+02	0.256E-03	0.528E-03	0.106E+03	0.995E-03	0.236E-02	0.137E+03	0.305E-02	0.753E-02	0.147E+03
TEST 8	0.488E-04	0.432E-04	-.115E+02	0.256E-03	0.207E-03	-.193E+02	0.995E-03	0.811E-03	-.185E+02	0.305E-02	0.252E-02	-.174E+02
TEST 9	0.488E-04	0.564E-04	0.157E+02	0.256E-03	0.232E-03	-.937E+01	0.995E-03	0.779E-03	-.217E+02	0.305E-02	0.228E-02	-.254E+02
TEST 10	0.488E-04	0.506E-04	0.364E+01	0.256E-03	0.282E-03	0.102E+02	0.995E-03	0.115E-02	0.154E+02	0.305E-02	0.362E-02	0.188E+02
TEST 11	0.488E-04	0.587E-04	0.203E+02	0.256E-03	0.288E-03	0.125E+02	0.995E-03	0.102E-02	0.292E+01	0.305E-02	0.305E-02	-.679E-02
TEST 12	0.488E-04	0.418E-04	-.144E+02	0.256E-03	0.150E-03	-.414E+02	0.995E-03	0.516E-03	-.482E+02	0.305E-02	0.151E-02	-.504E+02
TEST 13	0.488E-04	0.542E-04	0.111E+02	0.256E-03	0.310E-03	0.209E+02	0.995E-03	0.123E-02	0.238E+02	0.305E-02	0.382E-02	0.254E+02
TEST 14	0.488E-04	0.613E-04	0.257E+02	0.256E-03	0.266E-03	0.392E+01	0.995E-03	0.966E-03	-.294E+01	0.305E-02	0.292E-02	-.441E+01
TEST 15	0.488E-04	0.363E-04	-.255E+02	0.256E-03	0.236E-03	-.764E+01	0.995E-03	0.994E-03	-.150E+00	0.305E-02	0.313E-02	0.270E+01
TEST 16	0.488E-04	0.598E-04	0.225E+02	0.256E-03	0.315E-03	0.230E+02	0.995E-03	0.122E-02	0.228E+02	0.305E-02	0.370E-02	0.215E+02
TEST 17	0.488E-04	0.422E-04	-.135E+02	0.256E-03	0.236E-03	-.628E+01	0.995E-03	0.951E-03	-.443E+01	0.305E-02	0.298E-02	-.234E+01
TEST 18	0.488E-04	0.524E-04	0.739E+01	0.256E-03	[illegible]	0.251E+02	0.995E-03	0.131E-02	0.321E+02	0.305E-02	0.413E-02	0.353E+02
TEST 19	0.468E-04	0.291E-04	[illegible]	0.256E-03	0.166E-03	-.352E+02	0.995E-03	0.541E-03	-.456E+02	0.305E-02	0.155E-02	-.461E+02

Reproduced from best available copy.

TEST 20	0.400E-04	0.596E-04	0.222E+02	0.256E-03	0.273E-03	0.167E+02	0.995E-03	0.116E-02	0.171E+02	0.305E-02	0.354E-02	0.161E+02
TEST 21	0.400E-04	0.410E-04	-.161E+02	0.256E-03	0.179E-03	-.301E+02	0.995E-03	0.625E-03	-.292E+02	0.305E-02	0.174E-02	-.429E+02
TEST 22	0.400E-04	0.283E-04	-.420E+02	0.256E-03	0.164E-03	-.350E+02	0.995E-03	0.667E-03	-.310E+02	0.305E-02	0.219E-02	-.293E+02
TEST 23	0.400E-04	0.653E-04	0.337E+02	0.256E-03	0.247E-03	-.345E+01	0.995E-03	0.760E-03	-.236E+02	0.305E-02	0.216E-02	-.293E+02
TEST 24	0.400E-04	0.364E-04	-.254E+02	0.256E-03	0.101E-03	-.606E+02	0.995E-03	0.350E-03	-.640E+02	0.305E-02	0.104E-02	-.650E+02
TEST 25	0.400E-04	0.982E-04	0.101E+03	0.256E-03	0.325E-03	0.270E+02	0.995E-03	0.111E-02	0.111E+02	0.305E-02	0.323E-02	0.581E+01
TEST 26	0.400E-04	0.108E-03	0.250E+03	0.256E-03	0.410E-03	0.603E+02	0.995E-03	0.117E-02	0.175E+02	0.305E-02	0.335E-02	0.991E+01
TEST 27	0.400E-04	0.214E-03	0.339E+03	0.256E-03	0.442E-03	0.727E+02	0.995E-03	0.124E-02	0.242E+02	0.305E-02	0.351E-02	0.150E+02
TEST 28	0.400E-04	0.108E-03	0.286E+03	0.256E-03	0.380E-03	0.204E+02	0.995E-03	0.106E-02	0.629E+01	0.305E-02	0.335E-02	0.996E+01
TEST 29	0.400E-04	0.371E-03	0.660E+03	0.256E-03	0.607E-03	0.137E+03	0.995E-03	0.155E-02	0.557E+02	0.305E-02	0.462E-02	0.318E+02
TEST 30	0.400E-04	0.464E-03	0.843E+03	0.256E-03	0.650E-03	0.157E+03	0.995E-03	0.159E-02	0.597E+02	0.305E-02	0.417E-02	0.360E+02
TEST 31	0.400E-04	0.111E-02	0.217E+04	0.256E-03	0.111E-02	0.333E+03	0.995E-03	0.255E-02	0.156E+03	0.305E-02	0.556E-02	0.822E+02
TEST 32	0.400E-04	0.394E-02	0.790E+04	0.256E-03	0.514E-02	0.191E+04	0.995E-03	0.532E-02	0.434E+03	0.305E-02	0.952E-02	0.225E+03
TEST 33	0.400E-04	0.484E-02	0.981E+04	0.256E-03	0.725E-02	0.273E+04	0.995E-03	0.617E-02	0.521E+03	0.305E-02	0.117E-01	0.293E+03

[illegible]

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	[illegible] DISTANCE			200 m			500 m			1000 m		
	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.326E-05	0.999E-03	0.322E+05	0.170E-04	0.119E-01	0.696E+05	0.663E-04	0.909E-03	0.137E+04	0.203E-03	0.141E-02	0.596E+03
TEST 2	0.326E-05	0.275E-02	0.843E+05	0.170E-04	0.336E+01	0.198E+06	0.663E-04	0.511E-02	0.761E+04	0.203E-03	0.275E-02	0.125E+04
TEST 3	0.326E-05	0.316E-04	0.870E+03	0.170E-04	0.453E-04	0.166E+03	0.663E-04	0.112E-03	0.689E+02	0.203E-03	0.284E-03	0.398E+02
TEST 4	0.326E-05	0.922E-04	0.273E+04	0.170E-04	0.922E-04	0.442E+03	0.663E-04	0.175E-03	0.163E+03	0.203E-03	0.362E-03	0.781E+02
TEST 5	0.326E-05	0.523E-05	0.604E+02	0.170E-04	0.187E-04	0.103E+02	0.663E-04	0.671E-04	0.124E+01	0.203E-03	0.203E-03	0.109E+00
TEST 6	0.326E-05	0.142E-04	0.335E+03	0.170E-04	0.304E-04	0.790E+02	0.663E-04	0.865E-04	0.304E+02	0.203E-03	0.226E-03	0.115E+02
TEST 7	0.326E-05	0.447E-05	0.372E+02	0.170E-04	0.352E-04	0.107E+03	0.663E-04	0.157E-03	0.137E+03	0.203E-03	0.502E-03	0.147E+03
TEST 8	0.326E-05	0.288E-05	-.117E+02	0.170E-04	0.138E-04	-.189E+02	0.663E-04	0.541E-04	-.184E+02	0.203E-03	0.168E-03	-.173E+02
TEST 9	0.326E-05	0.376E-05	0.154E+02	0.170E-04	0.155E-04	-.901E+01	0.663E-04	0.519E-04	-.217E+02	0.203E-03	0.152E-03	-.253E+02
TEST 10	0.326E-05	0.337E-05	0.343E+01	0.170E-04	0.188E-04	0.106E+02	0.663E-04	0.766E-04	0.155E+02	0.203E-03	0.242E-03	0.190E+02
TEST 11	0.326E-05	0.391E-05	0.200E+02	0.170E-04	0.192E-04	0.130E+02	0.663E-04	0.683E-04	0.298E+01	0.203E-03	0.203E-03	0.157E+00
TEST 12	0.326E-05	0.279E-05	-.146E+02	0.170E-04	0.100E-04	-.412E+02	0.663E-04	0.344E-04	-.481E+02	0.203E-03	0.101E-03	-.503E+02
TEST 13	0.326E-05	0.361E-05	0.109E+02	0.170E-04	0.206E-04	0.214E+02	0.663E-04	0.822E-04	0.239E+02	0.203E-03	0.255E-03	0.256E+02
TEST 14	0.326E-05	0.409E-05	0.254E+02	0.170E-04	0.177E-04	0.433E+01	0.563E-04	0.644E-04	-.289E+01	0.203E-03	0.194E-03	-.425E+01
TEST 15	0.326E-05	0.242E-05	-.257E+02	0.170E-04	0.158E-04	-.728E+01	0.663E-04	0.662E-04	-.994E-01	0.203E-03	0.209E-03	0.295E+01
TEST 16	0.326E-05	0.399E-05	0.223E+02	0.170E-04	0.210E-04	0.235E+02	0.663E-04	0.814E-04	0.228E+02	0.203E-03	0.247E-03	0.217E+02
TEST 17	0.326E-05	0.281E-05	-.138E+02	0.170E-04	0.157E-04	-.764E+01	0.663E-04	0.634E-04	-.438E+01	0.203E-03	0.199E-03	-.218E+01
TEST 18	0.326E-05	0.349E-05	0.717E+01	0.170E-04	0.213E-04	0.256E+02	0.663E-04	0.875E-04	[illegible]	0.203E-03	0.275E-03	0.356E+02
TEST 19	0.326E-05	[illegible]	[illegible]	0.170E-04	[illegible]	[illegible]	0.663E-04	0.374E-04	-.435E+02	0.203E-03	0.110E-03	-.460E+02

Reproduced from
best available copy.

C, B-22

TEST 20	0.326E-05	0.339E-05	0.220E+02	0.170E-04	0.139E-04	0.171E+02	0.663E-04	0.777E-04	0.171E+02	0.203E-03	0.236E-03	0.163E+02
TEST 21	0.326E-05	0.273E-05	-.162E+02	0.170E-04	0.119E-04	-.298E+02	0.663E-04	0.403E-04	-.392E+02	0.203E-03	0.116E-03	-.428E+02
TEST 22	0.326E-05	0.189E-05	-.421E+02	0.170E-04	0.110E-04	-.355E+02	0.663E-04	0.458E-04	-.310E+02	0.203E-03	0.146E-03	-.281E+02
TEST 23	0.326E-05	0.435E-05	0.334E+02	0.170E-04	0.165E-04	-.307E+01	0.663E-04	0.507E-04	-.235E+02	0.203E-03	0.144E-03	-.292E+02
TEST 24	0.326E-05	0.243E-05	-.256E+02	0.170E-04	0.673E-05	-.604E+02	0.663E-04	0.234E-04	-.648E+02	0.203E-03	0.695E-04	-.658E+02
TEST 25	0.326E-05	0.655E-05	0.101E+03	0.170E-04	0.217E-04	0.275E+02	0.663E-04	0.737E-04	0.111E+02	0.203E-03	0.215E-03	0.590E+01
TEST 26	0.326E-05	0.120E-04	0.268E+03	0.170E-04	0.274E-04	0.610E+02	0.663E-04	0.780E-04	0.176E+02	0.203E-03	0.223E-03	0.999E+01
TEST 27	0.326E-05	0.143E-04	0.338E+03	0.170E-04	0.295E-04	0.734E+02	0.663E-04	0.824E-04	0.243E+02	0.203E-03	0.234E-03	0.152E+02
TEST 28	0.326E-05	0.126E-04	0.285E+03	0.170E-04	0.206E-04	0.209E+02	0.663E-04	0.785E-04	0.634E+01	0.203E-03	0.224E-03	0.101E+02
TEST 29	0.326E-05	0.247E-04	0.658E+03	0.170E-04	0.405E-04	0.130E+03	0.663E-04	0.103E-03	0.558E+02	0.203E-03	0.260E-03	0.320E+02
TEST 30	0.326E-05	0.307E-04	0.841E+03	0.170E-04	0.438E-04	0.158E+03	0.663E-04	0.106E-03	0.598E+02	0.203E-03	0.278E-03	0.371E+02
TEST 31	0.326E-05	0.739E-04	0.217E+04	0.170E-04	0.739E-04	0.335E+03	0.663E-04	0.170E-03	0.156E+03	0.203E-03	0.378E-03	0.825E+02
TEST 32	0.326E-05	0.263E-03	0.796E+04	0.170E-04	0.343E-03	0.192E+04	0.663E-04	0.354E-03	0.434E+03	0.203E-03	0.661E-03	0.226E+03
TEST 33	0.326E-05	0.322E-03	0.979E+04	0.170E-04	0.463E-03	0.274E+04	0.663E-04	0.412E-03	0.521E+03	0.203E-03	0.779E-03	0.284E+03

TEST 20	0.271E-02	0.331E-02	[illegible]	0.142E-01	0.166E-01	[illegible]	0.553E-01	0.647E-01	[illegible]	0.170E+00	0.137E+00	0.157E+02
TEST 21	0.271E-02	0.228E-02	-.160E+02	0.142E-01	0.995E-02	-.297E+02	0.553E-01	0.336E-01	-.393E+02	0.170E+00	0.968E-01	-.431E+02
TEST 22	0.271E-02	0.157E-02	-.419E+02	0.142E-01	0.913E-02	-.357E+02	0.553E-01	0.381E-01	-.310E+02	0.170E+00	0.122E+00	-.284E+02
TEST 23	0.271E-02	0.363E-02	0.330E+02	0.142E-01	0.137E-01	-.330E+01	0.553E-01	0.422E-01	-.236E+02	0.170E+00	0.120E+00	-.295E+02
TEST 24	0.271E-02	0.202E-02	-.254E+02	0.142E-01	0.561E-02	-.605E+02	0.553E-01	0.195E-01	-.648E+02	0.170E+00	0.579E-01	-.657E+02
TEST 25	0.271E-02	0.546E-02	0.101E+03	0.142E-01	0.181E-01	0.272E+02	0.553E-01	0.614E-01	0.110E+02	0.170E+00	0.179E+00	0.546E+01
TEST 26	0.271E-02	0.377E-02	0.269E+03	0.142E-01	0.228E-01	0.606E+02	0.553E-01	0.650E-01	0.175E+02	0.170E+00	0.186E+00	0.945E+01
TEST 27	0.271E-02	0.119E-01	0.340E+03	0.142E-01	0.246E-01	0.730E+02	0.553E-01	0.687E-01	0.242E+02	0.170E+00	0.195E+00	0.146E+02
TEST 28	0.271E-02	0.105E-01	0.286E+03	0.142E-01	0.171E-01	0.206E+02	0.553E-01	0.588E-01	0.624E+01	0.170E+00	0.186E+00	0.960E+01
TEST 29	0.271E-02	0.286E-01	0.650E+03	0.142E-01	0.337E-01	0.138E+03	0.553E-01	0.861E-01	0.557E+02	0.170E+00	0.223E+00	0.314E+02
TEST 30	0.271E-02	0.256E-01	0.843E+03	0.142E-01	0.365E-01	0.157E+03	0.553E-01	0.883E-01	0.397E+02	0.170E+00	0.232E+00	0.364E+02
TEST 31	0.271E-02	0.616E-01	0.217E+04	0.142E-01	0.616E-01	0.334E+03	0.553E-01	0.142E+00	0.156E+03	0.170E+00	0.309E+00	0.816E+02
TEST 32	0.271E-02	0.219E+00	0.798E+04	0.142E-01	0.285E+00	0.191E+04	0.553E-01	0.295E+00	0.434E+03	0.170E+00	0.551E+00	0.224E+03
TEST 33	0.271E-02	0.259E+00	0.981E+04	0.142E-01	0.483E+00	0.274E+04	0.553E-01	0.343E+00	0.529E+03	0.170E+00	0.649E+00	0.282E+03

C-B-24

Lead

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE			200 m			500 m			1000 m		
	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.271E-02	0.824E+00	0.303E+05	0.142E-01	0.988E+01	0.694E+05	0.553E-01	0.824E+00	0.139E+04	0.170E+00	0.118E+01	0.592E+03
TEST 2	0.271E-02	0.229E+01	0.845E+05	0.142E-01	0.280E+02	0.197E+06	0.553E-01	0.426E+01	0.768E+04	0.170E+00	0.229E+01	0.125E+04
TEST 3	0.271E-02	0.264E-01	0.873E+03	0.142E-01	0.377E-01	0.166E+03	0.553E-01	0.933E-01	0.688E+02	0.170E+00	0.236E+00	0.391E+02
TEST 4	0.271E-02	0.768E-01	0.274E+04	0.142E-01	0.768E-01	0.441E+03	0.553E-01	0.145E+00	0.163E+03	0.170E+00	0.301E+00	0.773E+02
TEST 5	0.271E-02	0.438E-02	0.600E+02	0.142E-01	0.156E-01	0.100E+02	0.553E-01	0.559E-01	0.115E+01	0.170E+00	0.169E+00	-.382E+00
TEST 6	0.271E-02	0.118E-01	0.337E+03	0.142E-01	0.254E-01	0.786E+02	0.553E-01	0.721E-01	0.303E+02	0.170E+00	0.189E+00	0.110E+02
TEST 7	0.271E-02	0.373E-02	0.375E+02	0.142E-01	0.293E-01	0.107E+03	0.553E-01	0.131E+00	0.137E+03	0.170E+00	0.418E+00	0.146E+03
TEST 8	0.271E-02	0.240E-02	-.114E+02	0.142E-01	0.115E-01	-.191E+02	0.553E-01	0.451E-01	-.185E+02	0.170E+00	0.140E+00	-.177E+02
TEST 9	0.271E-02	0.314E-02	0.157E+02	0.142E-01	0.129E-01	-.923E+01	0.553E-01	0.433E-01	-.218E+02	0.170E+00	0.126E+00	-.256E+02
TEST 10	0.271E-02	0.281E-02	0.368E+01	0.142E-01	0.157E-01	0.104E+02	0.553E-01	0.638E-01	0.154E+02	0.170E+00	0.201E+00	0.184E+02
TEST 11	0.271E-02	0.326E-02	0.203E+02	0.142E-01	0.160E-01	0.127E+02	0.553E-01	0.569E-01	0.288E+01	0.170E+00	0.169E+00	-.334E+00
TEST 12	0.271E-02	0.232E-02	-.144E+02	0.142E-01	0.834E-02	-.413E+02	0.553E-01	0.287E-01	-.482E+02	0.170E+00	0.841E-01	-.505E+02
TEST 13	0.271E-02	0.301E-02	0.111E+02	0.142E-01	0.172E-01	0.211E+02	0.553E-01	0.685E-01	0.238E+02	0.170E+00	0.212E+00	0.250E+02
TEST 14	0.271E-02	0.341E-02	0.257E+02	0.142E-01	0.148E-01	0.409E+01	0.553E-01	0.537E-01	-.298E+01	0.170E+00	0.162E+00	-.472E+01
TEST 15	0.271E-02	0.203E-02	-.252E+02	0.142E-01	0.131E-01	-.758E+01	0.553E-01	0.552E-01	-.190E+00	0.170E+00	0.174E+00	0.244E+01
TEST 16	0.271E-02	0.332E-02	0.226E+02	0.142E-01	0.173E-01	0.222E+02	0.553E-01	0.677E-01	0.227E+02	0.170E+00	0.206E+00	0.211E+02
TEST 17	0.271E-02	[illegible]	[illegible]	0.142E-01	0.131E-01	-.765E+01	0.553E-01	0.528E-01	-.446E+01	0.170E+00	0.165E+00	-.266E+01
TEST 18	0.271E-02	[illegible]	0.764E+01	0.142E-01	[illegible]	[illegible]	0.553E-01	[illegible]	[illegible]	0.170E+00	0.229E+00	0.349E+02
TEST 19	0.271E-02	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.553E-01	[illegible]	[illegible]	0.170E+00	0.914E-01	-.462E+02

C-B-26

Reproduced from best available copy.

Mercury

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE			200 m			500 m			1000 m		
	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.326E-02	0.909E+00	0.302E+05	0.170E-01	0.119E+02	0.696E+05	0.663E-01	0.389E+00	0.137E+04	0.203E+00	0.141E+01	0.596E+03
TEST 2	0.326E-02	0.275E+01	0.843E+05	0.170E-01	0.335E+04	0.198E+06	0.663E-01	0.511E+01	0.761E+04	0.203E+00	0.275E+01	0.125E+04
TEST 3	0.326E-02	0.316E-01	0.870E+03	0.170E-01	0.453E-01	0.166E+03	0.663E-01	0.112E+00	0.689E+02	0.203E+00	0.284E+00	0.399E+02
TEST 4	0.326E-02	0.922E-01	0.273E+04	0.170E-01	0.922E-01	0.442E+03	0.663E-01	0.175E+00	0.163E+03	0.203E+00	0.362E+00	0.781E+02
TEST 5	0.326E-02	0.523E-02	0.604E+02	0.170E-01	0.187E-01	0.103E+02	0.663E-01	0.671E-01	0.124E+01	0.203E+00	0.203E+00	0.189E+00
TEST 6	0.326E-02	0.142E-01	0.335E+03	0.170E-01	0.304E-01	0.790E+02	0.663E-01	0.865E-01	0.304E+02	0.203E+00	0.226E+00	0.115E+02
TEST 7	0.326E-02	0.447E-02	0.372E+02	0.170E-01	0.352E-01	0.107E+03	0.663E-01	0.157E+00	0.137E+03	0.203E+00	0.502E+00	0.147E+03
TEST 8	0.326E-02	0.288E-02	-.117E+02	0.170E-01	0.138E-01	-.189E+02	0.663E-01	0.541E-01	-.184E+02	0.203E+00	0.168E+00	-.173E+02
TEST 9	0.326E-02	0.376E-02	0.154E+02	0.170E-01	0.155E-01	-.901E+01	0.663E-01	0.519E-01	-.217E+02	0.203E+00	0.152E+00	-.253E+02
TEST 10	0.326E-02	0.337E-02	0.343E+01	0.170E-01	0.188E-01	0.106E+02	0.663E-01	0.766E-01	0.155E+02	0.203E+00	0.242E+00	0.190E+02
TEST 11	0.326E-02	0.391E-02	0.200E+02	0.170E-01	0.192E-01	0.130E+02	0.663E-01	0.683E-01	0.290E+01	0.203E+00	0.203E+00	0.157E+00
TEST 12	0.326E-02	0.279E-02	-.146E+02	0.170E-01	0.100E-01	-.412E+02	0.663E-01	0.344E-01	-.481E+02	0.203E+00	0.101E+00	-.503E+02
TEST 13	0.326E-02	0.361E-02	0.109E+02	0.170E-01	0.206E-01	0.214E+02	0.663E-01	0.822E-01	0.239E+02	0.203E+00	0.255E+00	0.256E+02
TEST 14	0.326E-02	0.409E-02	0.254E+02	0.170E-01	0.177E-01	0.433E+01	0.663E-01	0.644E-01	-.289E+01	0.203E+00	0.194E+00	-.425E+01
TEST 15	0.326E-02	0.242E-02	-.257E+02	0.170E-01	0.158E-01	-.720E+01	0.663E-01	0.662E-01	-.933E-01	0.203E+00	0.209E+00	0.275E+01
TEST 16	0.326E-02	0.399E-02	0.223E+02	0.170E-01	0.210E-01	0.235E+02	0.663E-01	0.814E-01	0.228E+02	0.203E+00	0.247E+00	0.217E+02
TEST 17	0.326E-02	0.281E-02	-.138E+02	0.170E-01	0.157E-01	-.784E+01	0.663E-01	0.634E-01	-.438E+01	0.203E+00	0.199E+00	-.218E+01
TEST 18	0.326E-02	0.349E-02	0.717E+01	0.172E-01	0.213E-01	[illegible]	0.663E-01	0.876E-01	[illegible]	0.203E+00	0.275E+00	0.356E+02

Reproduced from best available copy.

C-B-26

TEST 20	0.326E-02	0.390E-02	0.220E+02	0.170E-01	0.179E-01	0.171E+02	0.663E-01	0.777E-01	0.171E+02	0.203E+00	0.235E+00	0.163E+02
TEST 21	0.326E-02	0.273E-02	-.162E+02	0.170E-01	0.119E-01	-.298E+02	0.663E-01	0.403E-01	-.332E+02	0.203E+00	0.116E+00	-.429E+02
TEST 22	0.326E-02	0.189E-02	-.421E+02	0.170E-01	0.110E-01	-.355E+02	0.663E-01	0.450E-01	-.310E+02	0.203E+00	0.146E+00	-.281E+02
TEST 23	0.326E-02	0.435E-02	0.334E+02	0.170E-01	0.165E-01	-.307E+01	0.663E-01	0.507E-01	-.235E+02	0.203E+00	0.144E+00	-.292E+02
TEST 24	0.326E-02	0.243E-02	-.256E+02	0.170E-01	0.673E-02	-.604E+02	0.663E-01	0.234E-01	-.648E+02	0.203E+00	0.695E-01	-.658E+02
TEST 25	0.326E-02	0.655E-02	0.101E+03	0.170E-01	0.217E-01	0.275E+02	0.663E-01	0.737E-01	0.111E+02	0.203E+00	0.215E+00	0.598E+01
TEST 26	0.326E-02	0.120E-01	0.260E+03	0.170E-01	0.274E-01	0.610E+02	0.663E-01	0.760E-01	0.176E+02	0.203E+00	0.223E+00	0.999E+01
TEST 27	0.326E-02	0.143E-01	0.330E+03	0.170E-01	0.295E-01	0.734E+02	0.663E-01	0.824E-01	0.243E+02	0.203E+00	0.234E+00	0.152E+02
TEST 28	0.326E-02	0.125E-01	0.285E+03	0.170E-01	0.286E-01	0.289E+02	0.663E-01	0.785E-01	0.634E+01	0.203E+00	0.224E+00	0.181E+02
TEST 29	0.326E-02	0.247E-01	0.658E+03	0.170E-01	0.405E-01	0.130E+03	0.663E-01	0.103E+00	0.558E+02	0.203E+00	0.260E+00	0.320E+02
TEST 30	0.326E-02	0.307E-01	0.841E+03	0.170E-01	0.430E-01	0.158E+03	0.663E-01	0.106E+00	0.598E+02	0.203E+00	0.278E+00	0.371E+02
TEST 31	0.326E-02	0.735E-01	0.217E+04	0.170E-01	0.735E-01	0.335E+03	0.663E-01	0.170E+00	0.156E+03	0.203E+00	0.370E+00	0.825E+02
TEST 32	0.326E-02	0.253E+00	0.796E+04	0.170E-01	0.343E+00	0.192E+04	0.663E-01	0.354E+00	0.434E+03	0.203E+00	0.661E+00	0.225E+03
TEST 33	0.326E-02	0.322E+00	0.979E+04	0.170E-01	0.463E+00	0.274E+04	0.663E-01	0.412E+00	0.521E+03	0.203E+00	0.779E+00	0.284E+03

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

	MAXIMUM DISTANCE			200 m			500 m			1000 m		
CASE NO.	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.597E-04	0.181E-01	0.303E+05	0.313E-03	0.217E+00	0.693E+05	0.122E-02	0.181E-01	0.139E+04	0.373E-02	0.259E-01	0.594E+03
TEST 2	0.597E-04	0.504E-01	0.844E+05	0.313E-03	0.617E+02	0.197E+08	0.122E-02	0.937E-01	0.758E+04	0.373E-02	0.504E-01	0.125E+04
TEST 3	0.597E-04	0.580E-03	0.872E+03	0.313E-03	0.830E-03	0.165E+03	0.122E-02	0.205E-02	0.683E+02	0.373E-02	0.520E-02	0.395E+02
TEST 4	0.597E-04	0.169E-02	0.273E+04	0.313E-03	0.169E-02	0.440E+03	0.122E-02	0.320E-02	0.162E+03	0.373E-02	0.663E-02	0.777E+02
TEST 5	0.597E-04	0.959E-04	0.606E+02	0.313E-03	0.344E-03	0.981E+01	0.122E-02	0.123E-02	0.869E+00	0.373E-02	0.373E-02	-.350E-01
TEST 6	0.597E-04	0.262E-03	0.338E+03	0.313E-03	0.558E-03	0.783E+02	0.122E-02	0.159E-02	0.297E+02	0.373E-02	0.415E-02	0.113E+02
TEST 7	0.597E-04	0.820E-04	0.373E+02	0.313E-03	0.645E-03	0.106E+03	0.122E-02	0.285E-02	0.133E+03	0.373E-02	0.920E-02	0.147E+03
TEST 8	0.597E-04	0.528E-04	-.116E+02	0.313E-03	0.253E-03	-.193E+02	0.122E-02	0.992E-03	-.187E+02	0.373E-02	0.308E-02	-.175E+02
TEST 9	0.597E-04	0.690E-04	0.156E+02	0.313E-03	0.284E-03	-.940E+01	0.122E-02	0.952E-03	-.220E+02	0.373E-02	0.278E-02	-.254E+02
TEST 10	0.597E-04	0.618E-04	0.355E+01	0.313E-03	0.345E-03	0.102E+02	0.122E-02	0.140E-02	0.151E+02	0.373E-02	0.443E-02	0.187E+02
TEST 11	0.597E-04	0.717E-04	0.202E+02	0.313E-03	0.352E-03	0.125E+02	0.122E-02	0.125E-02	0.260E+01	0.373E-02	0.373E-02	-.664E-01
TEST 12	0.597E-04	0.511E-04	-.145E+02	0.313E-03	0.183E-03	-.414E+02	0.122E-02	0.630E-03	-.483E+02	0.373E-02	0.185E-02	-.504E+02
TEST 13	0.597E-04	0.663E-04	0.110E+02	0.313E-03	0.378E-03	0.209E+02	0.122E-02	0.151E-02	0.235E+02	0.373E-02	0.467E-02	0.253E+02
TEST 14	0.597E-04	0.750E-04	0.256E+02	0.313E-03	0.325E-03	0.389E+01	0.122E-02	0.118E-02	-.325E+01	0.373E-02	0.356E-02	-.447E+01
TEST 15	0.597E-04	0.444E-04	-.256E+02	0.313E-03	0.289E-03	-.768E+01	0.122E-02	0.121E-02	-.468E+00	0.373E-02	0.383E-02	0.272E+01
TEST 16	0.597E-04	0.731E-04	0.224E+02	0.313E-03	0.385E-03	0.230E+02	0.122E-02	0.149E-02	0.224E+02	0.373E-02	0.453E-02	0.214E+02
TEST 17	0.597E-04	0.515E-04	-.137E+02	0.313E-03	0.288E-03	-.803E+01	0.122E-02	0.116E-02	-.472E+01	0.373E-02	0.364E-02	-.240E+01
TEST 18	0.597E-04	0.641E-04	0.729E+01	0.313E-03	0.391E-03	0.250E+02	0.122E-02	0.161E-02	0.317E+02	0.373E-02	0.504E-02	0.353E+02
TEST 19	0.597E-04	0.356E-04	-.404E+02	0.313E-03	0.203E-03	-.352E+02	0.122E-02	0.686E-03	-.438E+02	0.373E-02	0.201E-02	-.461E+02

Reproduced from best available copy.

TEST 20	0.597E-04	0.729E-04	0.221E+02	0.213E-03	0.365E-03	0.166E+02	0.122E-02	0.142E-02	0.167E+02	0.373E-02	0.433E-02	0.160E+02
TEST 21	0.597E-04	0.501E-04	-.161E+02	0.313E-03	0.219E-03	-.301E+02	0.122E-02	0.733E-03	-.394E+02	0.373E-02	0.213E-02	-.429E+02
TEST 22	0.597E-04	0.346E-04	-.420E+02	0.313E-03	0.201E-03	-.228E+02	0.122E-02	0.839E-03	-.312E+02	0.373E-02	0.268E-02	-.282E+02
TEST 23	0.597E-04	0.798E-04	0.336E+02	0.313E-03	0.382E-03	-.349E+01	0.122E-02	0.929E-03	-.238E+02	0.373E-02	0.264E-02	-.293E+02
TEST 24	0.597E-04	0.445E-04	-.295E+02	0.313E-03	0.123E-03	-.606E+02	0.122E-02	0.428E-03	-.649E+02	0.373E-02	0.127E-02	-.658E+02
TEST 25	0.597E-04	0.120E-03	0.101E+03	0.313E-03	0.397E-03	0.270E+02	0.122E-02	0.135E-02	0.107E+02	0.373E-02	0.394E-02	0.574E+01
TEST 26	0.597E-04	0.220E-03	0.260E+03	0.313E-03	0.505E-03	0.603E+02	0.122E-02	0.143E-02	0.172E+02	0.373E-02	0.409E-02	0.975E+01
TEST 27	0.597E-04	0.262E-03	0.329E+03	0.313E-03	0.540E-03	0.726E+02	0.122E-02	0.151E-02	0.230E+02	0.373E-02	0.429E-02	0.149E+02
TEST 28	0.597E-04	0.230E-03	0.286E+03	0.313E-03	0.377E-03	0.204E+02	0.122E-02	0.129E-02	0.595E+01	0.373E-02	0.410E-02	0.509E+01
TEST 29	0.597E-04	0.453E-03	0.659E+03	0.313E-03	0.742E-03	0.137E+03	0.122E-02	0.189E-02	0.552E+02	0.373E-02	0.491E-02	0.317E+02
TEST 30	0.597E-04	0.562E-03	0.842E+03	0.313E-03	0.884E-03	0.157E+03	0.122E-02	0.194E-02	0.592E+02	0.373E-02	0.510E-02	0.367E+02
TEST 31	0.597E-04	0.136E-02	0.217E+04	0.313E-03	0.136E-02	0.333E+03	0.122E-02	0.311E-02	0.155E+03	0.373E-02	0.679E-02	0.821E+02
TEST 32	0.597E-04	0.482E-02	0.797E+04	0.313E-03	0.628E-02	0.131E+04	0.122E-02	0.650E-02	0.432E+03	0.373E-02	0.121E-01	0.225E+03
TEST 33	0.597E-04	0.591E-02	0.988E+04	0.313E-03	0.886E-02	0.273E+04	0.122E-02	0.755E-02	0.519E+03	0.373E-02	0.143E-01	0.283E+03

C-B-29

PCBs

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE BASE ALLOW RATE	MAXIMUM DISTANCE ALLOW RATE	MAXIMUM DISTANCE % DIFF	200 m BASE ALLOW RATE	200 m ALLOW RATE	200 m % DIFF	500 m BASE ALLOW RATE	500 m ALLOW RATE	500 m % DIFF	1000 m BASE ALLOW RATE	1000 m ALLOW RATE	1000 m % DIFF
TEST 1	0.832E-05	0.253E-02	0.303E+05	0.436E-04	0.303E-01	0.694E+05	0.169E-03	0.253E-02	0.140E+04	0.520E-03	0.361E-02	0.594E+03
TEST 2	0.832E-05	0.703E-02	0.844E+05	0.436E-04	0.860E+01	0.197E+08	0.169E-03	0.131E-01	0.763E+04	0.520E-03	0.703E-02	0.125E+04
TEST 3	0.832E-05	0.809E-04	0.872E+03	0.436E-04	0.116E-03	0.166E+03	0.169E-03	0.286E-03	0.694E+02	0.520E-03	0.725E-03	0.395E+02
TEST 4	0.832E-05	0.236E-03	0.273E+04	0.436E-04	0.236E-03	0.440E+03	0.169E-03	0.446E-03	0.164E+03	0.520E-03	0.924E-03	0.777E+02
TEST 5	0.832E-05	0.134E-04	0.606E+02	0.436E-04	0.479E-04	0.988E+01	0.169E-03	0.172E-03	0.150E+01	0.520E-03	0.520E-03	-.467E-01
TEST 6	0.832E-05	0.363E-04	0.336E+03	0.436E-04	0.778E-04	0.784E+02	0.169E-03	0.221E-03	0.300E+02	0.520E-03	0.579E-03	0.113E+02
TEST 7	0.832E-05	0.114E-04	0.374E+02	0.436E-04	0.899E-04	0.106E+03	0.169E-03	0.402E-03	0.138E+03	0.520E-03	0.128E-02	0.147E+03
TEST 8	0.832E-05	0.736E-05	-.115E+02	0.436E-04	0.352E-04	-.192E+02	0.169E-03	0.138E-03	-.182E+02	0.520E-03	0.429E-03	-.175E+02
TEST 9	0.832E-05	0.962E-05	0.156E+02	0.436E-04	0.395E-04	-.934E+01	0.169E-03	0.133E-03	-.215E+02	0.520E-03	0.388E-03	-.254E+02
TEST 10	0.832E-05	0.862E-05	0.357E+01	0.436E-04	0.481E-04	0.103E+02	0.169E-03	0.196E-03	0.158E+02	0.520E-03	0.617E-03	0.187E+02
TEST 11	0.832E-05	0.100E-04	0.202E+02	0.436E-04	0.491E-04	0.126E+02	0.169E-03	0.174E-03	0.324E+01	0.520E-03	0.520E-03	-.780E-01
TEST 12	0.832E-05	0.712E-05	-.144E+02	0.436E-04	0.256E-04	-.414E+02	0.169E-03	0.879E-04	-.480E+02	0.520E-03	0.258E-03	-.504E+02
TEST 13	0.832E-05	0.924E-05	0.110E+02	0.436E-04	0.527E-04	0.210E+02	0.169E-03	0.210E-03	0.242E+02	0.520E-03	0.651E-03	0.253E+02
TEST 14	0.832E-05	0.104E-04	0.256E+02	0.436E-04	0.453E-04	0.396E+01	0.169E-03	0.165E-03	-.264E+01	0.520E-03	0.497E-03	-.448E+01
TEST 15	0.832E-05	0.619E-05	-.256E+02	0.436E-04	0.403E-04	-.761E+01	0.169E-03	0.169E-03	0.157E+00	0.520E-03	0.534E-03	0.270E+01
TEST 16	0.832E-05	0.102E-04	0.225E+02	0.436E-04	0.537E-04	0.231E+02	0.169E-03	0.208E-03	0.232E+02	0.520E-03	0.631E-03	0.214E+02
TEST 17	0.832E-05	0.719E-05	-.136E+02	0.436E-04	0.401E-04	-.797E+01	0.169E-03	0.162E-03	-.413E+01	0.520E-03	0.507E-03	-.241E+01
TEST 18	0.832E-05	0.693E-05	0.732E+01	0.436E-04	0.546E-04	0.251E+02	0.169E-03	0.224E-03	0.325E+02	0.520E-03	0.703E-03	0.352E+02
TEST 19	0.832E-05	0.436E-05	-.403E+02	0.436E-04	[illegible]	-.352E+02	0.169E-03	[illegible]	-.434E+02	0.520E-03	0.280E-03	-.461E+02

C-6-30

Reproduced from
best available copy.

TEST 20	0.832E-05	0.182E-04	0.221E+02	0.436E-04	0.599E-04	0.167E+02	0.169E-03	0.198E-03	0.174E+02	0.520E-03	0.683E-03	0.160E+02
TEST 21	0.832E-05	0.698E-05	-.161E+02	0.436E-04	0.395E-04	-.308E+02	0.169E-03	0.103E-03	-.391E+02	0.520E-03	0.297E-03	-.427E+02
TEST 22	0.832E-05	0.483E-05	-.420E+02	0.436E-04	0.288E-04	-.358E+02	0.169E-03	0.117E-03	-.308E+02	0.520E-03	0.373E-03	-.262E+02
TEST 23	0.832E-05	0.111E-04	0.336E+02	0.436E-04	0.421E-04	-.342E+01	0.169E-03	0.130E-03	-.233E+02	0.520E-03	0.367E-03	-.293E+02
TEST 24	0.832E-05	0.629E-05	-.255E+02	0.436E-04	0.172E-04	-.695E+02	0.169E-03	0.597E-04	-.647E+02	0.520E-03	0.178E-03	-.658E+02
TEST 25	0.832E-05	0.167E-04	0.181E+03	0.436E-04	0.554E-04	0.270E+02	0.169E-03	0.188E-03	0.114E+02	0.520E-03	0.558E-03	0.573E+01
TEST 26	0.832E-05	0.386E-04	0.258E+03	0.436E-04	0.699E-04	0.604E+02	0.169E-03	0.199E-03	0.179E+02	0.520E-03	0.571E-03	0.974E+01
TEST 27	0.832E-05	0.365E-04	0.339E+03	0.436E-04	0.753E-04	0.728E+02	0.169E-03	0.211E-03	0.246E+02	0.520E-03	0.597E-03	0.149E+02
TEST 28	0.832E-05	0.321E-04	0.288E+03	0.436E-04	0.525E-04	0.285E+02	0.169E-03	0.108E-03	0.661E+01	0.520E-03	0.571E-03	0.988E+01
TEST 29	0.832E-05	0.632E-04	0.659E+03	0.436E-04	0.103E-03	0.137E+03	0.169E-03	0.254E-03	0.562E+02	0.520E-03	0.685E-03	0.317E+02
TEST 30	0.832E-05	0.784E-04	0.842E+03	0.436E-04	0.112E-03	0.157E+03	0.169E-03	0.271E-03	0.682E+02	0.520E-03	0.711E-03	0.367E+02
TEST 31	0.832E-05	0.109E-03	0.217E+04	0.436E-04	0.109E-03	0.333E+03	0.169E-03	0.434E-03	0.157E+03	0.520E-03	0.947E-03	0.821E+02
TEST 32	0.832E-05	0.672E-03	0.797E+04	0.436E-04	0.875E-03	0.191E+04	0.169E-03	0.986E-03	0.436E+03	0.520E-03	0.169E-02	0.225E+03
TEST 33	0.832E-05	0.824E-03	0.988E+04	0.436E-04	0.124E-02	0.273E+04	0.169E-03	0.185E-02	0.522E+03	0.520E-03	0.199E-02	0.283E+03

Toxaphene

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE			200 m			500 m			1000 m		
	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.561E-04	0.170E-01	0.303E+05	0.294E-03	0.204E+00	0.693E+05	0.114E-02	0.170E-01	0.139E+04	0.350E-02	0.243E-01	0.595E+03
TEST 2	0.561E-04	0.474E-01	0.843E+05	0.294E-03	0.579E+02	0.197E+08	0.114E-02	0.880E-01	0.762E+04	0.350E-02	0.474E-01	0.125E+04
TEST 3	0.561E-04	0.545E-03	0.871E+03	0.294E-03	0.780E-03	0.165E+03	0.114E-02	0.193E-02	0.692E+02	0.350E-02	0.489E-02	0.396E+02
TEST 4	0.561E-04	0.159E-02	0.273E+04	0.294E-03	0.159E-02	0.440E+03	0.114E-02	0.301E-02	0.164E+03	0.350E-02	0.623E-02	0.779E+02
TEST 5	0.561E-04	0.901E-04	0.605E+02	0.294E-03	0.323E-03	0.982E+01	0.114E-02	0.116E-02	0.141E+01	0.350E-02	0.350E-02	0.775E-01
TEST 6	0.561E-04	0.244E-03	0.336E+03	0.294E-03	0.524E-03	0.783E+02	0.114E-02	0.149E-02	0.306E+02	0.350E-02	0.390E-02	0.114E+02
TEST 7	0.561E-04	0.770E-04	0.373E+02	0.294E-03	0.606E-03	0.106E+03	0.114E-02	0.271E-02	0.138E+03	0.350E-02	0.864E-02	0.147E+03
TEST 8	0.561E-04	0.496E-04	-.116E+02	0.294E-03	0.237E-03	-.193E+02	0.114E-02	0.932E-03	-.183E+02	0.350E-02	0.289E-02	-.174E+02
TEST 9	0.561E-04	0.648E-04	0.155E+02	0.294E-03	0.266E-03	-.939E+01	0.114E-02	0.894E-03	-.216E+02	0.350E-02	0.261E-02	-.254E+02
TEST 10	0.561E-04	0.581E-04	0.351E+01	0.294E-03	0.324E-03	0.102E+02	0.114E-02	0.132E-02	0.157E+02	0.350E-02	0.416E-02	0.189E+02
TEST 11	0.561E-04	0.674E-04	0.201E+02	0.294E-03	0.331E-03	0.125E+02	0.114E-02	0.118E-02	0.314E+01	0.350E-02	0.350E-02	0.461E-01
TEST 12	0.561E-04	0.480E-04	-.145E+02	0.294E-03	0.172E-03	-.414E+02	0.114E-02	0.592E-03	-.481E+02	0.350E-02	0.174E-02	-.504E+02
TEST 13	0.561E-04	0.623E-04	0.110E+02	0.294E-03	0.355E-03	0.209E+02	0.114E-02	0.141E-02	0.241E+02	0.350E-02	0.439E-02	0.254E+02
TEST 14	0.561E-04	0.704E-04	0.255E+02	0.294E-03	0.305E-03	0.390E+01	0.114E-02	0.111E-02	-.274E+01	0.350E-02	0.335E-02	-.436E+01
TEST 15	0.561E-04	0.417E-04	-.256E+02	0.294E-03	0.271E-03	-.767E+01	0.114E-02	0.114E-02	0.613E-01	0.350E-02	0.360E-02	0.283E+01
TEST 16	0.561E-04	0.687E-04	0.224E+02	0.294E-03	0.362E-03	0.230E+02	0.114E-02	0.140E-02	0.230E+02	0.350E-02	0.425E-02	0.215E+02
TEST 17	0.561E-04	0.484E-04	-.137E+02	0.294E-03	0.270E-03	-.802E+01	0.114E-02	0.107E-02	-.422E+01	0.350E-02	0.342E-02	-.229E+01
TEST 18	0.561E-04	0.602E-04	0.733E+01	0.294E-03	0.368E-03	0.250E+02	0.114E-02	0.151E-02	0.324E+02	0.350E-02	0.474E-02	0.354E+02
TEST 19	0.561E-04	0.350E-04	-.376E+02	0.294E-03	[illegible]	[illegible]	0.114E-02	0.644E-03	-.435E+02	0.350E-02	0.193E-02	-.448E+02

C-13-32

TEST 20	0.561E-04	0.685E-04	0.221E+02	0.294E-03	0.343E-03	0.166E+02	0.114E-02	0.134E-02	0.173E+02	0.350E-02	0.407E-02	0.162E+02
TEST 21	0.561E-04	0.470E-04	-.162E+02	0.294E-03	0.206E-03	-.301E+02	0.114E-02	0.694E-03	-.391E+02	0.350E-02	0.200E-02	-.428E+02
TEST 22	0.561E-04	0.325E-04	-.420E+02	0.294E-03	0.189E-03	-.350E+02	0.114E-02	0.788E-03	-.304E+02	0.350E-02	0.251E-02	-.281E+02
TEST 23	0.561E-04	0.749E-04	0.336E+02	0.294E-03	0.284E-03	-.340E+01	0.114E-02	0.873E-03	-.234E+02	0.350E-02	0.240E-02	-.292E+02
TEST 24	0.561E-04	0.410E-04	-.255E+02	0.294E-03	0.116E-03	-.606E+02	0.114E-02	0.402E-03	-.647E+02	0.350E-02	0.120E-02	-.650E+02
TEST 25	0.561E-04	0.113E-03	0.101E+03	0.294E-03	0.373E-03	0.270E+02	0.114E-02	0.127E-02	0.113E+02	0.350E-02	0.371E-02	0.506E+01
TEST 26	0.561E-04	0.206E-03	0.260E+03	0.294E-03	0.471E-03	0.603E+02	0.114E-02	0.134E-02	0.178E+02	0.350E-02	0.385E-02	0.937E+01
TEST 27	0.561E-04	0.246E-03	0.339E+03	0.294E-03	0.588E-03	0.727E+02	0.114E-02	0.142E-02	0.245E+02	0.350E-02	0.403E-02	0.150E+02
TEST 28	0.561E-04	0.216E-03	0.286E+03	0.294E-03	0.354E-03	0.204E+02	0.114E-02	0.121E-02	0.651E+01	0.350E-02	0.385E-02	0.100E+02
TEST 29	0.561E-04	0.428E-03	0.659E+03	0.294E-03	0.697E-03	0.137E+03	0.114E-02	0.170E-02	0.561E+02	0.350E-02	0.462E-02	0.319E+02
TEST 30	0.561E-04	0.528E-03	0.842E+03	0.294E-03	0.755E-03	0.157E+03	0.114E-02	0.182E-02	0.601E+02	0.350E-02	0.479E-02	0.369E+02
TEST 31	0.561E-04	0.127E-02	0.217E+04	0.294E-03	0.127E-02	0.333E+03	0.114E-02	0.293E-02	0.157E+03	0.350E-02	0.638E-02	0.823E+02
TEST 32	0.561E-04	0.453E-02	0.797E+04	0.294E-03	0.598E-02	0.191E+04	0.114E-02	0.610E-02	0.435E+03	0.350E-02	0.114E-01	0.225E+03
TEST 33	0.561E-04	0.555E-02	0.980E+04	0.294E-03	0.833E-02	0.273E+04	0.114E-02	0.709E-02	0.522E+03	0.350E-02	0.134E-01	0.283E+03

C-B-53

n,1 C

ALLOWABLE EMISSIONS AT SPECIFIED RECEPTOR, g/s

CASE NO.	MAXIMUM DISTANCE			200 m			500 m			1000 m		
	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF	BASE ALLOW RATE	ALLOW RATE	% DIFF
TEST 1	0.253E-02	0.770E+00	0.303E+05	0.133E-01	0.922E+01	0.692E+05	0.516E-01	0.770E+00	0.139E+04	0.158E+00	0.110E+01	0.595E+03
TEST 2	0.253E-02	0.214E+01	0.845E+05	0.133E-01	0.262E+04	0.197E+08	0.516E-01	0.398E+01	0.761E+04	0.158E+00	0.214E+01	0.125E 04
TEST 3	0.253E-02	0.246E-01	0.873E+03	0.133E-01	0.352E-01	0.165E+03	0.516E-01	0.871E-01	0.688E+02	0.158E+00	0.221E+00	0.397E+02
TEST 4	0.253E-02	0.717E-01	0.273E+04	0.133E-01	0.717E-01	0.439E+03	0.516E-01	0.136E+00	0.163E+03	0.158E+00	0.281E+00	0.780E+02
TEST 5	0.253E-02	0.407E-02	0.608E+02	0.133E-01	0.146E-01	0.963E+01	0.516E-01	0.522E-01	0.118E+01	0.158E+00	0.158E+00	0.118E+00
TEST 6	0.253E-02	0.110E-01	0.336E+03	0.133E-01	0.237E-01	0.780E+02	0.516E-01	0.673E-01	0.303E+02	0.158E+00	0.176E+00	0.114E+02
TEST 7	0.253E-02	0.348E-02	0.375E+02	0.133E-01	0.274E-01	0.106E+03	0.516E-01	0.122E+00	0.137E+03	0.158E+00	0.390E+00	0.147E+03
TEST 8	0.253E-02	0.224E-02	-.115E+02	0.133E-01	0.107E-01	-.194E+02	0.516E-01	0.421E-01	-.185E+02	0.158E+00	0.131E+00	-.174E+02
TEST 9	0.253E-02	0.293E-02	0.157E+02	0.133E-01	0.120E-01	-.954E+01	0.516E-01	0.404E-01	-.217E+02	0.158E+00	0.118E+00	-.253E+02
TEST 10	0.253E-02	0.262E-02	0.366E+01	0.133E-01	0.146E-01	0.100E+02	0.516E-01	0.596E-01	0.154E+02	0.158E+00	0.188E+00	0.189E+02
TEST 11	0.253E-02	0.304E-02	0.203E+02	0.133E-01	0.149E-01	0.123E+02	0.516E-01	0.531E-01	0.291E+01	0.158E+00	0.158E+00	0.870E-01
TEST 12	0.253E-02	0.217E-02	-.144E+02	0.133E-01	0.778E-02	-.415E+02	0.516E-01	0.267E-01	-.482E+02	0.158E+00	0.785E-01	-.503E+02
TEST 13	0.253E-02	0.281E-02	0.111E+02	0.133E-01	0.161E-01	0.207E+02	0.516E-01	0.639E-01	0.238E+02	0.158E+00	0.198E+00	0.255E+02
TEST 14	0.253E-02	0.318E-02	0.257E+02	0.133E-01	0.138E-01	0.372E+01	0.516E-01	0.501E-01	-.296E+01	0.158E+00	0.151E+00	-.432E+01
TEST 15	0.253E-02	0.188E-02	-.255E+02	0.133E-01	0.123E-01	-.782E+01	0.516E-01	0.515E-01	-.164E+00	0.158E+00	0.163E+00	0.287E+01
TEST 16	0.253E-02	0.310E-02	0.226E+02	0.133E-01	0.163E-01	0.228E+02	0.516E-01	0.633E-01	0.228E+02	0.158E+00	0.192E+00	0.216E+02
TEST 17	0.253E-02	0.219E-02	-.136E+02	0.133E-01	0.122E-01	-.818E+01	0.516E-01	0.493E-01	-.444E+01	0.158E+00	0.154E+00	-.225E+01
TEST 18	0.253E-02	0.272E-02	0.741E+01	0.133E-01	0.166E-01	0.248E+02	0.516E-01	0.682E-01	0.321E+02	0.158E+00	0.214E+00	0.355E+02
TEST 19	0.253E-02	0.151E-02	-.403E+02	0.133E-01	0.860E-02	-.354E+02	0.516E-01	0.291E-01	-.436E+02	0.158E+00	0.853E-01	-.460E+02

TEST 20	0.253E-02	0.389E-02	0.222E+02	0.133E-01	0.155E-01	0.164E+02	0.516E-01	0.604E-01	0.170E+02	0.158E+00	0.184E+00	0.162E+02
TEST 21	0.253E-02	0.212E-02	-.160E+02	0.133E-01	0.929E-02	-.302E+02	0.516E-01	0.313E-01	-.392E+02	0.158E+00	0.903E-01	-.428E+02
TEST 22	0.253E-02	0.147E-02	-.419E+02	0.133E-01	0.852E-02	-.359E+02	0.516E-01	0.356E-01	-.310E+02	0.158E+00	0.114E+00	-.281E+02
TEST 23	0.253E-02	0.338E-02	0.337E+02	0.133E-01	0.120E-01	-.364E+01	0.516E-01	0.394E-01	-.236E+02	0.158E+00	0.112E+00	-.292E+02
TEST 24	0.253E-02	0.189E-02	-.254E+02	0.133E-01	0.524E-02	-.606E+02	0.516E-01	0.182E-01	-.640E+02	0.158E+00	0.541E-01	-.658E+02
TEST 25	0.253E-02	0.589E-02	0.101E+03	0.133E-01	0.169E-01	0.267E+02	0.516E-01	0.573E-01	0.111E+02	0.158E+00	0.167E+00	0.591E+01
TEST 26	0.253E-02	0.932E-02	0.269E+03	0.133E-01	0.213E-01	0.600E+02	0.516E-01	0.606E-01	0.175E+02	0.158E+00	0.174E+00	0.992E+01
TEST 27	0.253E-02	0.111E-01	0.339E+03	0.133E-01	0.229E-01	0.724E+02	0.516E-01	0.641E-01	0.242E+02	0.158E+00	0.182E+00	0.151E+02
TEST 28	0.253E-02	0.977E-02	0.286E+03	0.133E-01	0.160E-01	0.282E+02	0.516E-01	0.540E-01	0.627E+01	0.158E+00	0.174E+00	0.101E+02
TEST 29	0.253E-02	0.198E-01	0.660E+03	0.133E-01	0.315E-01	0.137E+03	0.516E-01	0.804E-01	0.557E+02	0.158E+00	0.208E+00	0.319E+02
TEST 30	0.253E-02	0.279E-01	0.843E+03	0.133E-01	0.341E-01	0.156E+03	0.516E-01	0.824E-01	0.597E+02	0.158E+00	0.216E+00	0.370E+02
TEST 31	0.253E-02	0.575E-01	0.217E+04	0.133E-01	0.575E-01	0.332E+03	0.516E-01	0.132E+00	0.156E+03	0.158E+00	0.288E+00	0.824E+02
TEST 32	0.253E-02	0.204E+00	0.798E+04	0.133E-01	0.266E+00	0.198E+04	0.516E-01	0.276E+00	0.434E+03	0.158E+00	0.514E+00	0.225E+03
TEST 33	0.253E-02	0.251E+00	0.901E+04	0.133E-01	0.376E+00	0.273E+04	0.516E-01	0.328E+00	0.528E+03	0.158E+00	0.686E+00	0.284E+03

APPENDIX D

Background Information on the Risk of PIC Emissions from Sewage Sludge Incinerators

MIDWEST RESEARCH INSTITUTE

MRI REPORT

BACKGROUND INFORMATION ON THE RISK OF ORGANIC EMISSIONS FROM SEWAGE SLUDGE INCINERATORS

DRAFT FINAL REPORT

EPA Prime Contract No. 68-01-7287
Work Assignment No. 36
MRI Project No. 9102-L(36)

December 2, 1988

Prepared for

U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Attn: Mr. Eugene Crumpler

MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 • 816 753-7600

D-4

BACKGROUND INFORMATION ON THE RISK OF ORGANIC EMISSIONS FROM SEWAGE SLUDGE INCINERATORS

DRAFT FINAL REPORT

EPA Prime Contract No. 68-01-7287
Work Assignment No. 36
MRI Project No. 9102-L(36)

December 2, 1988

Prepared for

U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Attn: Mr. Eugene Crumpler

MIDWEST RESEARCH INSTITUTE 425 VOLKER BOULEVARD, KANSAS CITY, MISSOURI 64110 • 816 753-7600

PREFACE

This draft report presents the background information for the development of a carcinogenic potency risk factor for sewage sludge incinerators. This report was prepared by Mr. Andrew Trenholm, with assistance from Ms. Deann Hecht and Mr. Greg Kautzman.

Approved:

MIDWEST RESEARCH INSTITUTE

James F Engel

James F. Engel
Deputy Program Manager

December 2, 1988

CONTENTS

Preface.. ii

1.0 Introduction.. 1
2.0 THC as a Surrogate for Total Organic Mass..................... 3
3.0 Development of a Carcinogenic Potency Risk Factor............ 11
4.0 References.. 20

Appendices

A. Emission data... A-1
B. C_1 and C_2 data... B-1
C. Molecular weight and response factor calculations............ C-1

SECTION 1.0

INTRODUCTION

The Office of Water is developing a regulatory approach that uses total hydrocarbon (THC) emissions as a measure of toxic organic emissions from hazardous waste incinerators. The approach involves developing a conservative potency risk factor for THC emissions based on available knowledge of specific organic emissions. This report discusses the data analysis and calculations necessary to perform this task for sewage sludge incinerators.

The destruction and removal efficiency (DRE) approach to control organic emissions from sewage sludge incinerators has some inherent limitations when used alone. First, the approach does not control the actual mass of principal organic hazardous constituents (POHCs) emitted, since for any given DRE, the mass emissions vary directly in proportion to variations in the mass feed rate. Also, the approach fails to account directly for emissions of products of incomplete combustion (PICs) that can be as toxic as, or more toxic than, the POHCs. Test data indicate that acceptable DREs cannot be achieved in sewage sludge incinerators. Apparently, organic constituents in the sludge are readily destroyed in the combustion zone, but organics are volatilized in the drying zone of the incinerator. Thus a DRE approach is not feasible for regulation of organic emissions from sewage sludge incinerators.

The risk posed by the emissions depends on the toxicity of the compounds emitted and the ambient levels to which persons are exposed. Limited information about organic compounds is available, and only five tests have been conducted to identify and quantify organic emissions from sewage sludge incinerators. Moreover, additional testing will not in the foreseeable future be able to prove quantitatively the negative--that organic emissions do not pose unacceptable health risk--because sampling and analysis techniques are not available to identify or quantify all potential compounds emitted, nor are toxicity data available for all compounds. Considering the uncertainties about organic emissions and their potential risk to public health, EPA believes it is prudent to require that sludge incinerators operate in a manner that reduces the potential for both organic compounds in the sludge and PICs to be emitted.

A conservative approach is to limit THC emissions as a surrogate for total organic emissions. The following sections describe this approach.

SECTION 2.0

THC AS A SURROGATE FOR TOTAL ORGANIC MASS

The applicability of THC monitors as a technique for monitoring the total mass emission of flue gas was evaluated. One issue is that THC monitors do not provide an accurate measure of the total organic mass emission rate of a combustion gas because the higher molecular weight compounds with low vapor pressure condense in the sample line and are not measured. A THC monitor has the capability to detect the presence of any hydrocarbon that is present in the vapor phase. If a heated inlet system is used, those compounds with low volatility would be less likely to condense in the inlet system and more likely to reach the monitor.

Data obtained from a study of hazardous waste incinerators[1] provides evidence supporting the use of THC as a total organic mass surrogate. Particularly useful is the information on the levels of specific semivolatile compounds adsorbed on resins in either the front half or back half of the MM5 train. These data are presented in Table 1. The distinction between the front half and back half is important, because if the less volatile compounds can remain in the vapor phase through the front half of an MM5 train, they almost certainly would remain in the vapor phase through the inlet system of a THC analyzer. The results show that in almost all cases, the semivolatiles are adsorbed in the back half resins, which indicates that they had readily entered the vapor phase, passed through the heated filter at 125°C, and been adsorbed. Data on the phthalate esters may be misleading since some of these compounds, principally the bis(2-ethylhexyl) ester, are often used as plasticizers in PVC and may be ubiquitous in laboratories. An overall average for all of the semivolatiles, excluding the phthalate esters, found in the back half is approximately 88%. If the filter temperature had been 150°C, which is

TABLE 1. ANALYSIS RESULTS FOR SEMIVOLATILES FROM SELECTED INCINERATORS

Incinerator site/semivolatile	Analysis of resin (μg) Back half	 Front half	% in Back half
Ross			
Phenol	ND	0.2	
Isophorone	9.7	ND	
2,4-Dimethylphenol	0.3	ND	
Fluoranthene	2.0	ND	
Pyrene	1.0	ND	
American Cyanamid			
Phenol	290	0.8[a]	99.7
o-Nitrophenol	110	2[a]	98.2
Naphthalene	140	0.2[a]	99.9
Bis(2-ethylhexyl) phthalate	72	3.4	95.5
TWI			
Naphthalene	24	1[a]	96.0
Di-*n*-butyl phthalate	12	2.1	85.1
Bis(2-ethylhexyl) phthalate	4.9	2.0	71.0
Mitchell			
Phenol	57	1[a]	98.3
Isophorone	0.6	0.2	75.0
2,4-Dimethylphenol	15	1.5[a]	90.9
Naphthalene	21	0.3[a]	98.6
Dodecanol	3.3	1[a]	76.7
Diethyl phthalate	210	46	82.0
Butylbenzyl phthalate	1.4	0.9	60.9
Bis(2-ethylhexyl) phthalate	7.1	15	32.1
DuPont			
trans-1,4-Dichloro-2-butene	2.0	2[a]	50.0
Phenol	50	1[a]	98.0
Naphthalene	240	1[a]	99.6
p-Chlorophenol	1.1	1[a]	52.4

[a] Levels were below limit of detection; levels shown are detection limits.

the inlet system temperature for THC monitors, the percentage may have been greater.

A specific example involves one of the least volatile compounds, 2,3,7,8-TCDD, which has a predicted boiling point of 447°C and a vapor pressure of 4 x 10^{-4} mm Hg at 125°C.[2] In a recent study by Rappe et al.,[3] it was found that 90% or more of low levels of TCDD passed through a filter heated to 150°C. At 100°C, variable quantities of the TCDD were found to pass through the filter.

The EPA Level 1 monitoring system, which is comprised of total volatile organics (C_1-C_6), total semivolatile organics (total chromatographable organics [TCO] and total nonvolatile organics (gravimetric [GRAV]), has been used for total hydrocarbon analysis and is presumed to account for all hydrocarbon emissions. Emission data for C_1-C_6, TCO, and GRAV analysis techniques have been compiled from EPA documents on various configured boilers. Table 2 presents the results for this monitoring system for 49 sites along with the site feed and combustor type, when available. In this analysis method, the C_1-C_6 hydrocarbons are determined using an integrated gas bag sample, injection of a portion of the gas sample into a GC, integration of the areas under the C_1, C_2, . . . C_6 peaks, and summation. The concentration of total semivolatile compounds is determined by adsorption onto the resins in the SASS train, desorption, and injection into a GC/MS for compound quantification. Total mass is determined from the cumulative area under all GC peaks. For the gravimetric method, the nonvolatile compounds are eluted from the adsorption resins used in the SASS train, the solvent stripped, and the samples weighed.

Table 3 presents an analysis of the composition data for the flue gas from the 49 sites in Table 2. This analysis shows the percentage of the total mass that is composed of 100% of the mass of the C_1-C_6 constituents plus 90% of the mass of the TCO constituents. The 90% figure was chosen for the semivolatile constituents based on the information presented earlier for the back half results and on the study by Rappe. Table 3 shows that 75% of the total organic mass would be detected by a THC monitor.

TABLE 2. SUMMARY OF FLUE GAS COMPOSITION

Case No.	Article title	Date	Feed type	Combustion source type	Site or test No.	C_1-C_6 concentration (mg/m^3)	Semivolatile concentration (TCO, mg/m^3)	Nonvolatile concentration (GRAV, mg/m^3)	Total concentration (mg/m^3)	% C_1-C_6	% TCO	% GRAV
1	Environmental Assessment of a Coal/Water Slurry Fired Industrial Boiler	May 1986	Coal/water			15.1	0.05	0.3	15.45	97.7	0.32	1.9
2	Environmental Assessment of Wood-Waste Fired Industrial Watertube Boiler	March 1987	Wood Wood		1 2	83.5 39.7	6.2 0.73	9.5 1.4	99.2 41.83	84.2 94.9	6.2 1.7	9.6 3.3
3	Environmental Assessment of a Crude Oil Heater Using Staged Air Lances for NO_x Reduction	July 1984	Baseline low NO_x			16.3 2.8	0.36 0.08	0.4 0.5	17.06 3.4	95.5 82.4	2.1 2.4	2.3 14.7
4	Environmental Assessment of an Enhanced Oil Recovery Steam Generator with Low NO_x Burner	May 1986				10.8	0.004	0.3	11.104	97.3	0.036	2.7
5	Environmental Assessment of a Water tube Boiler Firing Coal/Water Slurry	February 1984	Coal/water		2[a]	9.1	5.9	33.1	48.1	18.9	12.3	68.8
6	Environmental Assessment of a Fire-tube Boiler Firing Coal/Oil/Water Mixtures	September 1984	Coal/water/oil		C/O/W C/O/W+SA	3.8 4.1	0.04 0.02	2.9 9	6.74 13.12	56.4 31.3	0.59 0.15	43.0 68.6
7	Environmental Assessment of an Enhanced Recovery Steam Generator Equipped with an EPA Heavy Oil Low NO_x Burner	July 1966				b	0.17	0.13	0.3		56.7	43.3
8	Emissions Assessment of Conventional Stationary Combustion Systems Volume III: External Combustion Sources for Electricity Generation	November 1980	Coal	Pulverized Dry bottom	154	7.306	0.132	0.336	7.774	94.0	1.7	4.3
				Pulverized Wet bottom	206	46.19	0.874	3.301	50.365	91.7	1.7	6.6
					212	1.44	0.137	0.636	2.213	65.1	6.2	28.7
					213	5.26	0.082	0.306	5.648	93.1	1.5	5.4
					218	1.69	0.104	0.655	2.449	69.0	4.2	26.7
					336	2.28	2.83	1.815	6.925	32.9	40.9	26.2
					338	3.3	2.65	2.961	8.911	37.0	29.7	33.2
				Cyclone	134	3.87	0.773	1.295	5.938	65.2	13.0	21.8
					330	67.26	0.122	0.793	68.175	98.7	0.18	1.2
					331	14.14	9.92	3.304	27.364	51.7	36.3	12.1
				Stoker	137	0.902	0.227	2.508	3.637	24.8	6.2	69.0
					332	13.38	15.9	11.2	40.48	33.1	39.3	27.7

(continued)

TABLE 2. (continued)

Case No.	Article title	Date	Feed type	Combustion source type	Site or test No.	C_1-C_6 concentration (mg/m^3)	Semivolatile concentration (TCO, mg/m^3)	Nonvolatile concentration (GRAV, mg/m^3)	Total concentration (mg/m^3)	% C_1-C_6	% TCO	% GRAV
			Lignite	Pulverized Dry bottom	314	43.6	0.434	9.8	53.834	81.0	0.81	18.2
					315	7.01	0.936	6.93	14.876	47.1	6.3	46.6
					318	5	0.419	0.064	5.483	91.2	7.6	1.2
				Cyclone	155	7.97	0.196	0.49	8.656	92.1	2.3	5.7
					316	12.34	0.382	2.41	15.132	81.5	2.5	15.9
				Stoker	317	3.45	0.643	1.745	5.838	59.1	11.0	29.9
			Residual oil	Tangentially fired	210	4.97	0.104	0.839	5.913	84.1	1.8	14.2
					211	0.902	0.099	0.806	1.807	49.9	5.5	44.6
					322	4.14	0.592	2.149	6.881	60.2	8.6	31.2
					323	28.91	0.175	2.216	31.301	92.4	0.56	7.1
				Wall fired	118	4.17	0.071	0.375	4.616	90.3	1.5	8.1
					114-144	0.746	0.062	0.438	1.246	59.9	5.0	35.2
					324	2.07	1.02	2.074	5.2	40.1	19.8	40.2
			Natural gas	Wall fired	116	23.18	1.704	0.569	25.453	91.1	6.7	2.2
9	Emissions Assessment of Conventional Stationary Combustion Systems: Volume II. Commercial/Institutional Combustion Sources	October 1980	Gas		333	36.58	0.46	2.57	39.61	92.4	1.2	6.5
					352	0.808	0.11	0.31	1.228	65.8	9.0	25.2
			Distillate oil		139	2.58	0.523	0.129	3.232	79.8	16.2	4.0
					140	0.955	0.032	0.002	0.989	96.6	3.2	0.2
					339	4.34	3.152	15.22	22.712	19.1	13.9	67.0
			Residual oil		124	27.36	0.333	0.91	28.603	95.7	1.2	3.2
					138	4.54	0.059	0.53	5.129	88.5	1.2	10.3
					337	5.41	1.92	3.14	10.47	51.7	18.3	30.0
			Bituminous	Pulverized dry bottom	321	3.04	0.769	1.15	4.959	61.3	15.5	23.2
					343	10.19	0.243	4.41	14.843	68.7	1.6	29.7
				Stoker	325	1.73	2.388	2.73	6.848	25.3	34.9	39.9
					342	0.815	0.593	2.71	4.118	19.8	14.4	65.8
			Anthracite	Stoker	344	2.86	0.404	2.12	5.384	53.1	7.5	39.4
					345	1.51	0.116	1.43	3.056	49.4	3.8	46.8

---

[a] SASS train sampling not performed for Test 1.

[b] Only C_7 to C_{16} data available.

TABLE 3. PERCENT COMPOSITION OF FLUE GAS DUE TO VOLATILE AND SEMIVOLATILE COMPONENTS

Case no.	Site or test no.	C_1-C_5 (mg/m^3)	90% of TCO (mg/m^3)	Total concentration (mg/m^3)	% (C_1-C_5+90% TCO) of Total concentration
1		15.1	0.045	15.45	98.0
2	1	83.5	5.6	99.2	89.8
	2	39.7	0.66	41.83	96.5
3		16.3	0.32	17.06	97.4
4		10.8	0.0036	11.104	97.3
5		9.1	5.3	48.1	29.9
6		3.8	0.036	6.74	56.9
		4.1	0.018	13.12	31.4
7		-	0.15	0.3	50.0
8	154	7.306	0.119	7.774	95.5
	206	46.19	0.787	50.365	93.3
	212	1.44	0.123	2.213	70.6
	213	5.26	0.074	5.648	94.4
	218	1.69	0.094	2.449	72.8
	336	2.28	2.55	6.925	69.7
	338	3.3	2.39	8.911	63.9
	134	3.87	0.696	5.938	76.9
	330	67.26	0.11	68.175	98.8
	331	14.14	8.93	27.364	84.3
	137	0.902	0.204	3.637	30.4
	332	13.38	14.31	40.48	68.4
	314	43.6	0.391	53.834	81.7
	315	7.01	0.842	14.876	52.8
	318	5	0.377	5.483	98.1
	155	7.97	0.176	8.656	94.1
	316	12.34	0.344	15.132	83.8
	317	3.45	0.579	5.838	69.0
	210	4.97	0.0936	5.913	85.6
	211	0.902	0.089	1.807	54.8
	322	4.14	0.533	6.881	67.9
	323	28.91	0.158	31.301	92.9
	118	4.17	0.064	4.616	91.7
	114-144	0.746	0.056	1.246	64.4
	324	2.07	0.92	5.2	57.5
	116	23.18	1.534	25.453	97.1

(continued)

TABLE 3 (continued)

Case no.	Site or test no.	C_1-C_5 (mg/m^3)	90% of TCO (mg/m^3)	Total concentration (mg/m^3)	% (C_1-C_5+90% TCO) of Total concentration
9	333	36.58	0.41	39.61	93.4
	352	0.808	0.10	1.228	73.9
	139	2.58	0.471	3.232	94.4
	140	0.955	0.029	0.989	99.5
	339	4.34	2.837	22.712	31.6
	124	27.36	0.30	28.603	96.7
	138	4.54	0.053	5.129	89.5
	337	5.41	1.73	10.47	68.2
	321	3.04	0.692	4.959	75.3
	343	10.19	0.219	14.843	70.1
	325	1.73	2.149	6.848	56.6
	342	0.815	0.534	4.118	32.8
	344	2.86	0.364	5.384	59.9
	345	1.51	0.104	3.056	52.8
				Overall average	74.5

The above discussion would suggest that the use of a gas inlet system maintained at 150°C could result in the vapor phase transport of hydrocarbons with vapor pressures greater than 4×10^{-4} mm Hg from the stack sampling apparatus to the THC analyzer without any significant condensation of compounds in the inlet system. If this transport does occur, then the use of the THC monitor could provide an accurate surrogate for total organic mass.

SECTION 3.0

DEVELOPMENT OF A CARCINOGENIC POTENCY RISK FACTOR

A conservative carcinogenic potency risk factor for THC was developed for use in calculating allowable THC emission limits. This factor is used to calculate a reference air concentration, which is used with maximum dispersion coefficients and combustion gas flow rates to determine the THC limits. This calculation is shown in the following equation.

$$\text{THC} = \frac{\text{RAC} \times 3{,}240{,}000{,}000}{\text{DF} \times \text{GF}}$$

where: THC = Maximum allowable total hydrocarbon concentration in a sewage sludge incinerator stack, in parts per million at 7% oxygen.

RAC = Reference air concentration for THC, in micrograms per cubic meter.

DF = Dispersion factor, in micrograms per cubic meters per gram per second.

GF = Maximum gas flow from the sewage sludge incinerator, in gram moles per day.

3,240,000 = Correction factors.

The derivation of this equation is explained more fully in the "Technical Support Document for the Incineration of Sewage Sludge." This document covers development of the conservative carcinogenic potency risk factor for THC. The potency risk factor is a weighted carcinogenic potency (Q_1*) value based on organic compounds potentially emitted in stack gases during sewage sludge combustion. All compounds (including PCDDs and PCDFs) identified during tests of sewage sludge combustion were considered for these calculations, along with any other organic, carcinogenic compound listed in EPA's Integrated Risk Information System (IRIS). Table 4 lists all the compounds used to derive the conservative potency risk factor. All of the compounds listed and their emission concentrations are based on data from tests of sewage sludge incinerators except:

- All carcinogens identified in EPA's IRIS system with inhalation health effects data (potencies) but not detected in the incinerator tests are included at an assumed detection limit of 0.1 ng/L.
- Formaldehyde has been detected in the emissions of municipal waste incinerators and chloromethane in the emissions of hazardous waste incinerators, but were not measured in the emissions during the sludge incinerator tests. Concentrations for formaldehyde and chloromethane are based on data from tests of municipal and hazardous waste incinerators, respectively.
- Methane (C_1) and ethane, ethylene and acetylene (C_2) are known to be emitted in significant quantities from all combustion sources. This class of compounds were not measured directly during the sludge incinerator tests. To account for their presence in the stack gases, EPA combustion data from fossil fueled boilers, furnaces, and other sources were used to calculate concentrations for Table 4. These data are in Appendix B.

All of the emission concentrations where more than one data point was available were calculated as the upper 95th percent of the range of available data. The available data used to obtain the emission concentrations can be found in Appendix A. Two points should be noted about the test data. First, the units of concentration are reported as µg/dscm in the test documents; however, for consistency the equivalent units of ng/L are used in Table 4. Second, tetrachloroethene, perchloroethylene, and tetrachloroethylene are synonyms for the same chemical. However, the test documents report concentrations for tetrachloroethene and perchloroethylene in the volatile and semivolatile tables, respectively.

TABLE 4. WEIGHTED POTENCY RISK FACTOR

Compounds	Q* (day-kg/mg)	95% Emission conc. (ng/L)	Weight fraction	Weighted Q* (day-kg/mg)
Carcinogens				
Acrylamide	2.4E-01	0.1	1.8E-06	4.3E-07
Acrylonitrile	1.8E-01	1,024.7	1.8E-02	3.2E-03
Aldrin	1.8E+01	0.1	1.8E-06	3.1E-05
Aniline	2.5E-02	0.1	1.8E-06	4.4E-08
Benzene	2.9E-02	309.89	5.5E-03	1.6E-04
Benzidine	2.3E+02	0.1	1.8E-06	4.1E-04
Benzo[*a*]pyrene	1.2E+01	17.49	3.1E-04	3.6E-03
Bis(2-chloroethyl) ether	1.2E+00	0.1	1.8E-06	2.1E-06
Bis(chloromethyl) ether	2.2E+02	0.1	1.8E-06	3.9E-04
Bis(2-ethylhexyl) phthalate	8.4E-04	47.1	8.3E-04	7.0E-07
1,3-Butadiene	9.7E-01	0.1	1.8E-06	1.7E-06
Carbon tetrachloride	1.3E-01	1.86	3.3E-05	4.3E-06
Chlordane	1.3E+00	0.1	1.8E-06	2.3E-06
Chloroform	8.1E-02	211.85	3.8E-03	3.1E-04
Chloromethane	1.2E-02	450	8.0E-03	9.3E-05
Chloromethyl methyl ether	9.5E+00	0.1	1.8E-06	1.7E-05
DDD	2.4E-01	0.1	1.8E-06	4.3E-07
DDE	3.4E-01	0.1	1.8E-06	6.0E-07
DDT	3.4E-01	0.1	1.8E-06	6.0E-07
1,2-Dibromo-3-chloropropane	2.2E+01	0.1	1.8E-06	3.9E-05
1,2-Dibromoethane	7.8E-01	0.1	1.8E-06	1.4E-06
1,2-Dichloroethane	9.1E-02	1.27	2.3E-05	2.0E-06
1,1-Dichloroethylene	1.2E+00	1.03	1.8E-05	2.1E-05
Dieldrin	1.6E+01	0.1	1.8E-06	2.8E-05
Diethylstilbestrol	4.9E+02	0.1	1.8E-06	8.7E-04
Dioxane	4.9E-03	0.1	1.8E-06	8.7E-09
1,2-Diphenylhydrazine	8.0E-01	0.1	1.8E-06	1.4E-06
Epichlorohydrin	4.2E-03	0.1	1.8E-06	7.5E-09

(continued)

TABLE 4 (continued)

Compounds	Q* (day-kg/mg)	95% Emission conc. (ng/L)	Weight fraction	Weighted Q* (day-kg/mg)
Carcinogens (continued)				
Ethylene oxide	3.5E-01	0.1	1.8E-06	6.2E-07
Formaldehyde	4.4E-02	780	1.4E-02	6.0E-04
Heptachlor	4.5E+00	0.1	1.8E-06	8.1E-06
Heptachlor epoxide	9.1E+00	0.1	1.8E-06	1.6E-05
2,3,7,8-Heptachlorodibenzo-*p*-dioxin	1.8E+02	0.00052	9.2E-09	1.6E-06
other-Heptachlorodibenzo-*p*-dioxin	1.8E+00	0.00060	1.1E-08	1.9E-08
Hexachlorobutadiene	7.8E-02	0.1	1.8E-06	1.4E-07
α-Hexachlorocyclohexane	6.3E+00	0.1	1.8E-06	1.1E-05
beta-Hexachlorocyclohexane	1.8E+00	0.1	1.8E-06	3.3E-06
gamma-Hexachlorocyclohexane	1.3E-01	0.1	1.8E-06	2.3E-07
Hexachlorocyclohexane, technical	1.8E+00	0.1	1.8E-06	3.1E-06
2,3,7,8-Hexachlorodibenzo-*p*-dioxin	6.2E+03	0.00051	9.0E-09	5.6E-05
other-Hexachlorodibenzo-*p*-dioxin	7.0E+01	0.00220	3.9E-08	2.7E-06
Hexachloroethane	1.4E-02	0.77	1.4E-05	1.9E-07
3-Methylcholanthrene	9.5E+00	0.1	1.8E-06	1.7E-05
Methylene chloride	1.5E-02	83.75	1.5E-03	2.2E-05
4,4-Methylene-bis-2-chloroaniline	1.7E-01	0.1	1.8E-06	3.0E-07
Methyl hydrazine	1.2E+00	0.1	1.8E-06	2.1E-06
2-Nitropropane	2.0E+02	0.1	1.8E-06	3.5E-04
N-Nitrosodi-*n*-butylamine	5.6E+00	0.1	1.8E-06	9.8E-06
N-Nitrosodi-*n*-propylamine	7.0E+00	0.1	1.8E-06	1.3E-05
N-Nitrosodiethylamine	1.5E+02	0.1	1.8E-06	2.7E-04
N-Nitrosodimethylamine	4.9E+01	0.1	1.8E-06	8.7E-05
N-Nitrosopyrrolidine	2.2E+00	0.1	1.8E-06	3.9E-06
PCBs	7.0E+00	0.2	3.5E-06	2.5E-05
2,3,7,8-Pentachlorodibenzo-*p*-dioxin	8.8E+04	0.00014	2.5E-09	2.2E-04
other-Pentachlorodibenzo-*p*-dioxin	8.8E+02	0.00340	6.0E-08	5.3E-05
Pentachloronitrobenzene	2.5E-02	0.1	1.8E-06	4.4E-08

(continued)

TABLE 4 (continued)

Compounds	Q* (day-kg/mg)	95% Emission conc. (ng/L)	Weight fraction	Weighted Q* (day-kg/mg)
Carcinogens (continued)				
Pronamide	1.6E-02	0.1	1.8E-06	2.8E-08
Reserpine	1.1E+01	0.1	1.8E-06	1.9E-05
2,3,7,8-Tetrachlorodibenzofuran	1.8E+04	0.00370	6.6E-08	1.1E-03
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1.8E+05	0.00008	1.4E-09	2.5E-04
other-Tetrachlorodibenzo-p-dioxin	1.8E+03	0.00750	1.3E-07	2.3E-04
1,1,2,2-Tetrachloroethane	2.1E-01	0.1	1.8E-06	3.6E-07
Tetrachloroethylene	1.7E-03	228.77	4.1E-03	6.8E-06
Thiourea	1.9E+00	0.1	1.8E-06	3.4E-06
Toxaphene	1.1E+00	0.1	1.8E-06	2.0E-06
1,1,2-Trichloroethane	5.7E-02	0.1	1.8E-06	1.0E-07
Trichloroethylene	1.3E-02	120.21	2.1E-03	2.8E-05
2,4,6-Trichlorophenol	2.0E-02	0.1	1.8E-06	3.5E-08
Noncarcinogens				
Acetonitrile	0.0E+00	296.26	5.3E-03	0
Acetophenone	0.0E+00	0.1	1.8E-06	0
Allyl alcohol	0.0E+00	0.1	1.8E-06	0
Bromodichloromethane	0.0E+00	0.1	1.8E-06	0
Bromoform	0.0E+00	0.1	1.8E-06	0
Bromomethane	0.0E+00	0.1	1.8E-06	0
2-Chloro-1,3-butadiene	0.0E+00	0.1	1.8E-06	0
Cresols	0.0E+00	0.1	1.8E-06	0
Di-n-butyl phthalate	0.0E+00	0.1	1.8E-06	0
Dibromochloromethane	0.0E+00	0.1	1.8E-06	0
Dichlorodifluoromethane	0.0E+00	0.1	1.8E-06	0
2,4-Dichlorophenol	0.0E+00	40.03	7.1E-04	0
1,3-Dichloropropene	0.0E+00	0.1	1.8E-06	0

(continued)

TABLE 4 (continued)

Compounds	Q* (day-kg/mg)	95% Emission conc. (ng/L)	Weight fraction	Weighted Q* (day-kg/mg)
Noncarcinogens (continued)				
Diethyl phthalate	0.0E+00	0.1	1.8E-06	0
Dimethoate	0.0E+00	0.1	1.8E-06	0
2,4-Dinitrophenol	0.0E+00	260.95	4.6E-03	0
Diphenylamine	0.0E+00	0.1	1.8E-06	0
Endosulfan	0.0E+00	0.1	1.8E-06	0
Endrin	0.0E+00	0.1	1.8E-06	0
Ethylbenzene	0.0E+00	48.51	8.6E-04	0
Formic acid	0.0E+00	0.1	1.8E-06	0
Hexachlorocyclopentadiene	0.0E+00	0.1	1.8E-06	0
Hydrogen cyanamide	0.0E+00	0.1	1.8E-06	0
Isobutyl alcohol	0.0E+00	0.1	1.8E-06	0
Isophorone	0.0E+00	0.1	1.8E-06	0
Methomyl	0.0E+00	0.1	1.8E-06	0
Methoxychlor	0.0E+00	0.1	1.8E-06	0
Methyl ethyl ketone	0.0E+00	173.61	3.1E-03	0
Methyl parathion	0.0E+00	0.1	1.8E-06	0
Nitrobenzene	0.0E+00	3.17	5.6E-05	0
Pentachlorobenzene	0.0E+00	0.1	1.8E-06	0
Pentachlorophenol	0.0E+00	77.37	1.4E-03	0
Phenol	0.0E+00	119.25	2.1E-03	0
N-Phenylenediamine	0.0E+00	0.1	1.8E-06	0
Phenylmercuric acetate	0.0E+00	0.1	1.8E-06	0
Pyridine	0.0E+00	0.1	1.8E-06	0
Selenourea	0.0E+00	0.1	1.8E-06	0
Strychnine	0.0E+00	0.1	1.8E-06	0
1,2,4,5-Tetrachlorobenzene	0.0E+00	0.1	1.8E-06	0
2,3,4,6-Tetrachlorophenol	0.0E+00	0.1	1.8E-06	0
Tetraethyl lead	0.0E+00	0.1	1.8E-06	0

(continued)

TABLE 4 (continued)

Compounds	Q* (day-kg/mg)	95% Emission conc. (ng/L)	Weight fraction	Weighted Q* (day-kg/mg)
Noncarcinogens (continued)				
Toluene	0.0E+00	215.02	3.8E-03	0
1,2,4-Trichlorobenzene	0.0E+00	29.85	5.3E-04	0
1,1,1-Trichloroethane	0.0E+00	97.5	1.7E-03	0
Trichlorofluoromethane	0.0E+00	0.1	1.8E-06	0
2,4,5-Trichlorophenol	0.0E+00	0.1	1.8E-06	0
C_1 Hydrocarbons	0.0E+00	17,575	3.1E-01	0
C_2 Hydrocarbons	0.0E+00	34,200	6.1E-01	0
TOTAL		56,423.3		1.26E-02

The values for tetrachloroethene were used because the volatile organic sampling train (VOST) is a more accepted sampling method for this compound than the Modified Method 5 (MM5) for semivolatiles.

Noncarcinogens have zero carcinogenic potency but their total emission rate is included on Table 4 to account for their contribution to the total mass of emissions. For toxic substances not known to display carcinogenic properties, there appears to be an identifiable exposure threshold below which adverse health effects usually do not occur. Therefore, protection against the adverse health effects of a noncarcinogen is likely to be achieved by preventing total exposure levels from exceeding the threshold dose. EPA has therefore conservatively defined reference air concentrations (RACs) for noncarcinogenic compounds that are defined in terms of a fixed fraction of the estimated threshold concentration. It is assumed that the actual maximum ambient air concentrations for each compound will not exceed the RACs and would not cause adverse health effects. Therefore, in Table 4, zero was used in the potency column.

The weighted cancer potency (Q_1*) on Table 4 is obtained by multiplying the weight fraction of each carcinogen by the cancer potency to obtain the contribution of each carcinogen to the overall potency of THC. These contributions are added to obtain the total weighted potency value shown at the end of Table 4.

The weighted potency from Table 4 is used to calculate an acceptable risk specific dose (RSD) in units of $\mu g/m^3$. Conversion of this value into a THC emission value requires unit conversions, a dispersion factor, a gas flow rate, and three other factors. This conversion is described in the "Technical Support Document for the Incineration of Sewage Sludge." Development of the three other factors is described below. These factors are:

1. A weighted average molecular weight of the list of carcinogenic and noncarcinogenic compounds on Table 4, g/g-mole (34.0). This factor is used to convert from ppm by volume to a mass/volume concentration.

2. The ratio of response of propane (3.0) to the weighted average response of the list of compounds on Table 4 (1.8) to a flame ionization detector (FID), dimensionless (1.7). This factor adjusts for the varying response of a FID to different compounds.

3. A dimensionless factor to adjust the measured THC for the potential loss of heavy organics in the sampling system. This factor is based on a conservative analysis described in Section 2 of the fraction of the total organic mass emitted from combustion devices that is nonvolatile and, therefore, has potential to condense or be adsorbed in the sampling system precluding detection by the THC monitor (0.75).

Calculation of the weighted average molecular weight and response factor are shown in Appendix C.

SECTION 4.0

REFERENCES

1. Trenholm, A., P. Gorman, and G. Jungclaus, "Performance Evaluation of Full-Scale Hazardous Waste Incinerators. Volume 2 - Incinerator Performance Results," EPA-600/2-84-181b, PB85-129518, November 1984.

2. Rordorf, B. F., "Prediction of Vapor Pressures, Boiling Point, and Enthalpies of Fusion for 29 Halogenated Dibenzo-p-Dioxins and 66 Dibenzofurans by a Vapor Pressure Circulation Method," Proceedings of the 7th International Symposium on Chlorinated Dioxins and Related Compounds, Las Vegas, October 4-9, 1987.

3. Hagenmaier, H., M. Kraft, S. Marklund, and C. Rappe, "Studies Toward Validated Sampling of PCDDs and PCDFs in Stack Gas," Presented at the Dioxin 87 Meeting, Las Vegas, Nevada, October 1987.

APPENDIX A

EMISSION DATA

Data Summary for PICs
Emission Rate (ng/l)**

Municipal Sludge Incinerators	Test No.	Acrylonitrile	Acetonitrile	Benzene	MEK	Carbon Tet	Chloroform
Site 1	1	147.00		271.00		2.60	71.00
	2	383.00		411.00		2.40	92.50
	3	230.00		310.00		1.20	110.00
	4	157.00		189.00		1.20	81.00
	5	376.00		450.00		2.40	114.00
	Average:	258.60		326.20		1.96	93.70
Site 2	1	0.86		0.021		0.032	0.016
(Values from the control	2	0.85		0.021		0.032	0.016
device outlet)	3	0.86		0.022		0.032	0.016
	4	0.84		0.021		0.032	0.016
	5	0.82		0.021		0.031	0.015
	6	0.83		0.021		0.031	0.016
	Average:	0.84		0.021		0.032	0.016
Site 3	1	1.80 *		19.00		0.25 *	126.00
	2	1.83 *		45.00		0.26 *	540.00
	3	1.90 *		5.50		0.80	3.00
	Average:	1.84 *		23.17		0.44 *	223.00
Site 4	1	2,642.00		667.00	1,025.00	0.30	17.30
(Values from the control	2	407.00	189.00	123.00	6.70	0.97	27.40
device outlet)	3	3,325.00	1,145.00	498.00	0.00	1.56	31.90
	4	28.40	36.40	19.70	3.79	1.10	34.40
	5	23.70	36.60	6.13	2.16	0.37	27.20
	6	45.40	74.30	8.02	4.03	0.30	37.10
	Average:	1,078.58	296.26	220.31	173.61	0.77	29.22
Site 5	1						4.50
(Values from the control	2						4.60
device outlet)	3					0.30	6.60
	Average:					0.30	5.23
SITE AVERAGE - MIN		0.84		0.02		0.03	0.02
SITE AVERAGE - MAX		1,078.58		326.20		1.96	223.00
SITE AVERAGE - 95TH		1,024.70	296.26	309.89	173.61	1.86	211.85

* Detection Limits
** Reported as ug/dscm,
Dioxins/furan were reported in ng/dscm
and converted to ng/L

Data Summary for PICs
Emission Rate (ng/l)**

Municipal Sludge Incinerators	Test No.	1,2-Dichoro-ethane	Methylene Chloride	Tetrachloro-ethene	Toluene	Trichloro-ethene
Site 1	1	0.19	26.80	292.00	75.40	14.30
	2	0.10	46.90	417.00	109.00	35.10
	3	0.19	70.70	229.00	80.40	31.50
	4	0.33	55.50	161.00	69.00	16.70
	5	1.60	15.20	105.00	154.00	35.40
	Average:	0.48	43.02	240.80	97.56	26.60
Site 2 (Values from the control device outlet)	1	0.032	0.054	0.16	0.11	0.16
	2	0.032	0.053	0.16	0.11	0.16
	3	0.032	0.054	0.16	0.11	0.16
	4	0.032	0.060	0.16	0.11	0.16
	5	0.031	0.051	0.15	0.10	0.15
	6	0.031	0.052	0.15	0.10	0.15
	Average:	0.032	0.054	0.16	0.11	0.16
Site 3	1	0.30 *	5.80	0.27 *	1.10	0.30
	2	0.31 *	5.00	0.28 *	2.00	0.30 *
	3	0.32 *	1.40	8.60	8.40	0.90
	Average:	0.31 *	4.07	3.05 *	3.83	0.50 *
Site 4 (Values from the control device outlet)	1	0.00	149.00	102.00	551.00	176.00
	2	0.00	185.00	65.00	197.00	154.00
	3	0.00	110.00	100.00	478.00	123.00
	4	3.19	45.10	50.80	49.60	103.00
	5	1.12	12.90	41.40	19.90	74.20
	6	1.87	26.90	90.20	62.50	129.00
	Average:	1.03	88.15	74.90	226.33	126.53
Site 5 (Values from the control device outlet)	1	1.30	23.00			
	2	1.20	25.00			
	3	1.50	27.00			
	Average:	1.33	25.00			
SITE AVERAGE - MIN		0.03	0.05	0.16	0.11	0.16
SITE AVERAGE - MAX		1.33	88.15	240.80	226.33	126.53
SITE AVERAGE - 95TH		1.27	83.75	228.77	215.02	120.21

* Detection Limits

** Reported as ug/dscm,
Dioxins/furan were reported in ng/dscm
and converted to ng/L

Data Summary for PICs
Emission Rate (ng/l)**

Municipal Sludge Incinerators	Test No.	Bis (2-Ethyl hexyl) phthalate	Phenol	2,4-Dichloro-phenol	2,4-Dinitro-phenol	Pentachloro-phenol
Site 1	1	7.80	16.90 *	26.50 *	172.00 *	51.10 *
	2					
	3	55.20	19.60 *	30.70 *	199.50 *	59.20 *
	4	50.60 *	42.20 *	66.30 *	430.50 *	127.80 *
	5	42.60	28.50 *	44.70 *	290.20 *	86.20 *
	Average:	39.05 *	26.80 *	42.05 *	273.05 *	81.08 *
Site 2 (Values from the control device outlet)	1	191.00	173.00	2.40 *	43.40 *	9.50 *
	2	35.80	107.00	1.70 *	31.10 *	6.80 *
	3	36.40	208.00	1.50 *	27.70 *	6.00 *
	4	15.00	61.70	1.50 *	28.20 *	6.20 *
	5	7.20	153.00	1.50 *	27.90 *	6.10 *
	6	7.30	50.10	1.60 *	28.10 *	6.20 *
	Average:	48.78	125.47	1.70 *	31.07 *	6.80 *
Site 3	1	5.20	1.11 *	2.22 *	40.60 *	8.89 *
	2	30.50	1.07 *	2.14 *	39.00 *	8.55 *
	3	10.10	1.07 *	2.13 *	38.90 *	8.52 *
	Average:	15.27	1.08 *	2.16 *	39.50 *	8.65 *
Site 4 (Values from the control device outlet)	1		2.30			
	2		4.50			
	3		5.70			
	4					
	5					
	6					
	Average:		4.17			
Site 5 (Values from the control device outlet)	1		5.40		36.00	
	2		3.80		55.00	
	3		6.50		52.00	
	Average:		5.23		47.67	
SITE AVERAGE - MIN		15.27	1.08	1.70	31.07	6.80
SITE AVERAGE - MAX		48.78	125.47	42.05	273.05	81.08
SITE AVERAGE - 95TH		47.10	119.25	40.03	260.95	77.37

* Detection Limits
** Reported as ug/dscm,
Dioxins/furan were reported in ng/dscm
and converted to ng/L

Data Summary for PICs
Emission Rate (ng/l)**

Municipal Sludge Incinerators	Test No.	Benzo(a) pyrene	1,2,4-Tri-chlorobenzene	2378 TCDD	Other TCDD	2378 PCDD	Other PCDD
Site 1	1	11.60 *	19.80 *				
	2						
	3	13.40 *	22.90 *				
	4	28.90 *	49.40 *				
	5	19.50 *	33.30 *				
	Average:	18.35 *	31.35 *				
Site 2 (Values from the control device outlet)	1	1.80 *	2.40 *				
	2	0.90 *	1.30 *				
	3	1.10 *	1.10 *				
	4	1.10 *	1.10 *				
	5	1.10 *	1.10 *				
	6	1.20 *	1.20 *				
	Average:	1.20 *	1.37 *				
Site 3	1	1.67 *	1.67 *				
	2	1.60 *	1.60 *				
	3	1.60 *	1.60 *				
	Average:	1.62 *	1.62 *				
Site 4 (Values from the control device outlet)	1			0.0001200	0.00849	0.00012	0.00285
	2			0.0001400	0.00800	0.00020	0.00317
	3			0.0001200	0.00540	0.00012	0.00181
	4			0.0000200	0.00173	0.00003	0.00084
	5			0.0000010	0.01076	0.00020	0.00571
	6			0.0000800	0.01083	0.00019	0.00579
	Average:			0.0000802	0.0075350	0.0001433	0.0033617
Site 5 (Values from the control device outlet)	1						
	2						
	3						
	Average:						
SITE AVERAGE - MIN		1.20	1.37				
SITE AVERAGE - MAX		18.35	31.35				
SITE AVERAGE - 95TH		17.49	29.85	0.0000802	0.0075350	0.0001433	0.0033617

* Detection Limits

** Reported as ug/dscm,
Dioxins/furan were reported in ng/dscm
and converted to ng/L

Data Summary for PICs
Emission Rate (ng/l)**

Municipal Sludge Incinerators	Test No.	2378 HxCDD	Other HxCDD	2378 HpCDD	Other HpCDD	2378 TCDF	Ethylbenzene
Site 1	1						11.10
	2						13.40
	3						99.80
	4						13.30
	5						24.30
	Average:						32.38
Site 2 (Values from the control device outlet)	1						0.16
	2						0.16
	3						0.16
	4						0.16
	5						0.15
	6						0.15
	Average:						0.16
Site 3	1						0.30
	2						0.29
	3						2.50
	Average:						1.03
Site 4 (Values from the control device outlet)	1	0.00033	0.00185	0.00043	0.00048	0.00414	255.00
	2	0.00052	0.00183	0.00053	0.00058	0.00442	22.10
	3	0.00037	0.00144	0.00046	0.00048	0.00447	25.30
	4	0.00015	0.00072	0.00018	0.00021	0.00123	1.85
	5	0.00085	0.00393	0.00079	0.00104	0.00420	0.43
	6	0.00081	0.00367	0.00071	0.00080	0.00367	1.60
	Average:	0.0005050	0.0022400	0.0005167	0.0005983	0.0036883	51.05
Site 5 (Values from the control device outlet)	1						6.50
	2						8.70
	3						7.60
	Average:						7.60
SITE AVERAGE - MIN							0.16
SITE AVERAGE - MAX							51.05
SITE AVERAGE - 95TH		0.0005050	0.0022400	0.0005167	0.0005983	0.0036883	48.51

* Detection Limits

** Reported as ug/dscm,
Dioxins/furan were reported in ng/dscm
and converted to ng/L

Data Summary for PICs
Emission Rate (ng/l)**

Municipal Sludge Incinerators	Test No.	1,1,1 Trichloroethane	Hexachloroethane	Nitrobenzene	1,1-Dichloroethene	1,3-Dichloropropene
Site 1	1	3.30				
	2	6.20				
	3	6.30				
	4	9.10				
	5	2.80				
	Average:	5.54				
Site 2 (Values from the control device outlet)	1	0.037				
	2	0.037				
	3	0.038				
	4	0.037				
	5	0.036				
	6	0.036				
	Average:	0.04				
Site 3	1	2.60				
	2	2.10				
	3	2.80				
	Average:	2.50				
Site 4 (Values from the control device outlet)	1	63.70				
	2	162.00				
	3	113.00				
	4	78.00				
	5	73.00				
	6	125.00				
	Average:	102.45				
Site 5 (Values from the control device outlet)	1	6.50	0.60	2.90	1.20	
	2	5.70	0.90	3.00	0.70	
	3	5.80	0.80	3.60	1.20	0.10
	Average:	6.00	0.77	3.17	1.03	0.10
SITE AVERAGE - MIN		0.04				
SITE AVERAGE - MAX		102.63				
SITE AVERAGE - 95TH		97.50	0.77	3.17	1.03	0.10

* Detection Limits

** Reported as ug/dscm,
Dioxins/furan were reported in ng/dscm
and converted to ng/L

APPENDIX B

C_1 AND C_2 DATA

C_1 AND C_2 CONCENTRATIONS BASED ON DATA IN TABLE 2

Case no. from Table 2	Feed type	Test	C_1 (ng/L)	C_2 (ng/L)
2	Wood	1	18,500	36,000
		2	2,500	5,000
3		Baseline	0	3,600
		Low NO_X	0	2,800
4			200	0
5	Coal/water	1	3,500	10,500
		2	3,000	5,800
6	Coal/water/oil	1	0	900
		2	0	0
8	Coal	Dry bottom	3,330	0
		Wet bottom	3,330	630
		Cyclone	610	270
		Stoker	970	5,770
	Lignite	Dry bottom	2,570	810
		Cyclone	6,440	500
		Stoker	1,780	330
	Residual oil	Tangentially fired	1,450	260
		Wall fired	5,910	520
	Natural gas	Wall fired	330	330
10[a]			929	0

[a] Data from "Total Mass Emissions from a Hazardous Waste Incinerator," Final Report, MRI Project No. 8671-L(1).

APPENDIX C

MOLECULAR WEIGHT AND RESPONSE FACTOR CALCULATIONS

Average MW and Average Response Factor

Compound

Carcinogens	MW	95% Emission Conc. (ng/L)	Fraction Present	Average MW	Response Factor	Average Response Factor
Acrylamide	71.08	0.1	1.77E-06	1.26E-04	1.30	2.30E-06
Acrylonitrile	53.06	1024.7	1.82E-02	9.64E-01	1.93	3.51E-02
Aldrin	364.93	0.1	1.77E-06	6.47E-04	11.76	2.08E-05
Aniline	93.12	0.1	1.77E-06	1.65E-04	5.40	9.57E-06
Benzene	78.11	309.89	5.49E-03	4.29E-01	6.00	3.30E-02
Benzidine	184.23	0.1	1.77E-06	3.27E-04	10.80	1.91E-05
Benzo(a)pyrene	252.3	17.49	3.10E-04	7.82E-02	20.00	6.20E-03
Bis(2-chloroethyl) ether	143.02	0.1	1.77E-06	2.53E-04	3.00	5.32E-06
Bis(chloromethyl) ether	114.97	0.1	1.77E-06	2.04E-04	1.00	1.77E-06
Bis(2-ethylhexyl) phthalate	390.54	47.1	8.35E-04	3.26E-01	1.83	1.53E-03
1,3-Butadiene	54.09	0.1	1.77E-06	9.59E-05	3.80	6.73E-06
Carbon tetrachloride	153.84	1.86	3.30E-05	5.07E-03	0.64	2.11E-05
Chlordane	409.8	0.1	1.77E-06	7.26E-04	9.76	1.73E-05
Chloroform	119.39	211.85	3.75E-03	4.48E-01	0.85	3.19E-03
Chloromethane	50.49	450	7.98E-03	4.03E-01	0.95	7.58E-03
Chloromethyl methyl ether	80.51	0.1	1.77E-06	1.43E-04	1.00	1.77E-06
DDD	320.05	0.1	1.77E-06	5.67E-04	13.86	2.46E-05
DDE	316	0.1	1.77E-06	5.60E-04	13.86	2.46E-05
DDT	354.5	0.1	1.77E-06	6.28E-04	13.64	2.42E-05
1,2-Dibromo-3-chloropropane	236.36	0.1	1.77E-06	4.19E-04	3.00	5.32E-06
1,2-Dibromoethane	187.88	0.1	1.77E-06	3.33E-04	2.00	3.54E-06
1,2-Dichloroethane	98.97	1.27	2.25E-05	2.23E-03	1.60	3.60E-05
1,1-Dichloroethylene	96.95	1.03	1.83E-05	1.77E-03	1.90	3.47E-05
Dieldrin	380.93	0.1	1.77E-06	6.75E-04	10.76	1.91E-05
Diethylstilbestrol	268.34	0.1	1.77E-06	4.76E-04	15.30	2.71E-05
Dioxane	88.1	0.1	1.77E-06	1.56E-04	2.00	3.54E-06
1,2-Diphenylhydrazine	184.23	0.1	1.77E-06	3.27E-04	10.50	1.86E-05
Epichlorohydrin	92.53	0.1	1.77E-06	1.64E-04	2.00	3.54E-06
Ethylene oxide	44.05	0.1	1.77E-06	7.81E-05	1.00	1.77E-06
Formaldehyde	30.03	780	1.38E-02	4.15E-01	0.00	0.00E+00
Heptachlor	373.35	0.1	1.77E-06	6.62E-04	9.76	1.73E-05
Heptachlor epoxide	389.4	0.1	1.77E-06	6.90E-04	8.76	1.55E-05
2,3,7,8-Heptachlorodibenzo-p-dioxin	425.5	0.00052	9.22E-09	3.92E-06	11.50	1.06E-07
other-Heptachlorodibenzo-p-dioxin	425.5	0.00060	1.06E-08	4.52E-06	11.50	1.22E-07
Hexachlorobutadiene	260.76	0.1	1.77E-06	4.62E-04	4.30	7.62E-06
alpha-Hexachlorocyclohexane	290.85	0.1	1.77E-06	5.15E-04	6.00	1.06E-05
beta-Hexachlorocyclohexane	290.85	0.1	1.77E-06	5.15E-04	6.00	1.06E-05
gamma-Hexachlorocyclohexane	290.85	0.1	1.77E-06	5.15E-04	6.00	1.06E-05
Hexachlorocyclohexane, technical	290.85	0.1	1.77E-06	5.15E-04	6.00	1.06E-05
2,3,7,8-Hexachlorodibenzo-p-dioxin	391	0.00051	9.04E-09	3.53E-06	11.50	1.04E-07
other-Hexachlorodibenzo-p-dioxin	391	0.0022	3.90E-08	1.52E-05	11.50	4.48E-07
Hexachloroethane	236.74	0.77	1.36E-05	3.23E-03	1.28	1.75E-05
3-Methylcholanthrene	268.34	0.1	1.77E-06	4.76E-04	21.00	3.72E-05
Methylene chloride	84.94	83.75	1.48E-03	1.26E-01	0.90	1.34E-03
4,4-Methylene-bis-2-chloroaniline	267.16	0.1	1.77E-06	4.73E-04	11.80	2.09E-05
Methyl hydrazine	46.07	0.1	1.77E-06	8.17E-05	0.40	7.09E-07
2-Nitropropane	89.09	0.1	1.77E-06	1.58E-04	3.00	5.32E-06
N-Nitrosodi-N-butylamine	158.24	0.1	1.77E-06	2.80E-04	7.25	1.28E-05
N-Nitrosodi-N-propylamine	146.24	0.1	1.77E-06	2.59E-04	6.25	1.11E-05
N-Nitrosodiethylamine	102.14	0.1	1.77E-06	1.81E-04	2.65	4.70E-06
N-Nitrosodimethylamine	74.08	0.1	1.77E-06	1.31E-04	1.25	2.22E-06
N-Nitrosopyrrolidine	96.09	0.1	1.77E-06	1.70E-04	3.25	5.76E-06
PCBs	292	0.2	3.54E-06	1.04E-03	12.00	4.25E-05
2,3,7,8-pentachlorodibenzo-p-dioxin	356.5	0.00014	2.48E-09	8.85E-07	11.50	2.85E-08
other-pentachlorodibenzo-p-dioxin	356.5	0.0034	6.03E-08	2.15E-05	11.50	6.93E-07

Average MW and Average Response Factor

Pentachloronitrobenzene	295.36	0.1	1.77E-06	5.23E-04	5.00	8.86E-06
Pronamide	256.13	0.1	1.77E-06	4.54E-04	10.95	1.94E-05
Reserpine	608.7	0.1	1.77E-06	1.08E-03	30.25	5.36E-05
2,3,7,8-Tetrachlorodibenzofuran	306	0.0037	6.56E-08	2.01E-05	11.75	7.71E-07
2,3,7,8-Tetrachlorodibenzo-p-dioxin	322	0.00008	1.42E-09	4.57E-07	11.50	1.63E-08
other-Tetrachlorodibenzo-p-dioxin	322	0.0075	1.33E-07	4.28E-05	11.50	1.53E-06
1,1,2,2-Tetrachloroethane	167.86	0.1	1.77E-06	2.98E-04	1.20	2.13E-06
Tetrachloroethylene	165.85	228.77	4.05E-03	6.72E-01	1.10	4.46E-03
Thiourea	76.12	0.1	1.77E-06	1.35E-04	0.40	7.09E-07
Toxaphene	413.81	0.1	1.77E-06	7.33E-04		0.00E+00
1,1,2-Trichloroethane	133.42	0.1	1.77E-06	2.36E-04	1.50	2.66E-06
Trichloroethylene	131.4	120.21	2.13E-03	2.80E-01	1.50	3.20E-03
2,4,6-Trichlorophenol	197.46	0.1	1.77E-06	3.50E-04	5.40	9.57E-06

Non-carcinogens

Acetonitrile	41.05	296.26	5.25E-03	2.16E-01	1.30	6.83E-03
Acetophenone	120.15	0.1	1.77E-06	2.13E-04	7.00	1.24E-05
Allyl alcohol	58.08	0.1	1.77E-06	1.03E-04	2.30	4.08E-06
Bromodichloromethane	163.83	0.1	1.77E-06	2.90E-04	0.76	1.35E-06
Bromoform	252.77	0.1	1.77E-06	4.48E-04	1.00	1.77E-06
Bromomethane	94.95	0.1	1.77E-06	1.68E-04	0.95	1.68E-06
2-chloro-1,3-butadiene	88.54	0.1	1.77E-06	1.57E-04	3.60	6.38E-06
Cresols	108.13	0.1	1.77E-06	1.92E-04	6.40	1.13E-05
Di-n-butyl phthalate	278.34	0.1	1.77E-06	4.93E-04	13.50	2.39E-05
Dibromochloromethane	208.289	0.1	1.77E-06	3.69E-04	0.88	1.56E-06
Dichlorodifluoromethane	120.92	0.1	1.77E-06	2.14E-04	0.60	1.06E-06
2,4-Dichlorophenol	162	40.03	7.09E-04	1.15E-01	1.83	1.30E-03
1,3-Dichloropropene	110.98	0.1	1.77E-06	1.97E-04	2.90	5.14E-06
Diethyl phthalate	222.23	0.1	1.77E-06	3.94E-04	1.83	3.24E-06
Dimethoate	229.28	0.1	1.77E-06	4.06E-04	3.25	5.76E-06
2,4-Dinitrophenol	184.11	260.95	4.62E-03	8.51E-01	5.40	2.50E-02
Diphenylamine	169.22	0.1	1.77E-06	3.00E-04	11.25	1.99E-05
Endosulfan	406.95	0.1	1.77E-06	7.21E-04	8.76	1.55E-05
Endrin	380.93	0.1	1.77E-06	6.75E-04	10.76	1.91E-05
Ethylbenzene	94.16	48.51	8.60E-04	8.10E-02	8.00	6.88E-03
Formic acid	46.02	0.1	1.77E-06	8.16E-05	0.00	0.00E+00
Hexachlorocyclopentadiene	272.77	0.1	1.77E-06	4.83E-04	5.00	8.86E-06
Hydrogen cyanamide	42.04	0.1	1.77E-06	7.45E-05	0.30	5.32E-07
Isobutyl alcohol	74.12	0.1	1.77E-06	1.31E-04	3.75	6.65E-06
Isophorone	138.2	0.1	1.77E-06	2.45E-04	8.00	1.42E-05
Methomyl	162.2	0.1	1.77E-06	2.87E-04	7.75	1.37E-05
Methoxychlor	345.65	0.1	1.77E-06	6.13E-04	13.64	2.42E-05
Methyl ethyl ketone	72.1	173.61	3.08E-03	2.22E-01	1.83	5.63E-03
Methyl parathion	263.23	0.1	1.77E-06	4.67E-04	8.00	1.42E-05
Nitrobenzene	123.11	3.17	5.62E-05	6.92E-03	6.00	3.37E-04
Pentachlorobenzene	250.34	0.1	1.77E-06	4.44E-04	6.00	1.06E-05
Pentachlorophenol	266.35	77.37	1.37E-03	3.65E-01	1.83	2.51E-03
Phenol	94.11	119.25	2.11E-03	1.99E-01	1.83	3.87E-03
N-phenylenediamine	108.14	0.1	1.77E-06	1.92E-04	5.25	9.30E-06
Phenylmercuric acetate	336.75	0.1	1.77E-06	5.97E-04	6.00	1.06E-05
Pyridine	79.1	0.1	1.77E-06	1.40E-04	5.00	8.86E-06
Selenourea	123.02	0.1	1.77E-06	2.18E-04	0.40	7.09E-07
Strychnine	334.4	0.1	1.77E-06	5.93E-04	20.50	3.63E-05
1,2,4,5-Tetrachlorobenzene	215.89	0.1	1.77E-06	3.83E-04	6.00	1.06E-05
2,3,4,6-Tetrachlorophenol	231.89	0.1	1.77E-06	4.11E-04	5.40	9.57E-06
Tetraethyl lead	323.45	0.1	1.77E-06	5.73E-04	4.00	7.09E-06
Toluene	92.13	215.02	3.81E-03	3.51E-01	7.00	2.67E-02
1,2,4-Trichlorobenzene	181.46	29.85	5.29E-04	9.60E-02	1.83	9.68E-04
1,1,1 Trichloroethane	133.39	97.5	1.73E-03	2.30E-01	1.64	2.83E-03

Average MW and Average Response Factor

Trichlorofluoromethane	137.38	0.1	1.77E-06	2.43E-04	0.64	1.13E-06
2,4,5-Trichlorophenol	197.45	0.1	1.77E-06	3.50E-04	1.83	3.24E-06
C1 Hydrocarbons	16	17575	3.11E-01	4.98E+00	1.00	3.11E-01
C2 Hydrocarbons	30	34200	6.06E-01	1.82E+01	2.00	1.21E+00
		-------------		---------		---------
		56423		3.01E+01		1.70E+00

Note: Methane was assumed for C1 Hydrocarbons
Ethane was assumed for C2 Hydrocarbons
Tetra CB was assumed for PCBs

APPENDIX E

Statistical Analysis of Sludge Incinerator Emissions

DRAFT FINAL REPORT

DATA BASE DOCUMENTATION AND SUMMARY STATISTICS ON METALS' DESTRUCTION EFFICIENCY ESTIMATES FROM INCINERATION OF MUNICIPAL SLUDGE

Submitted to:

U.S. Environmental Protection Agency
Analysis and Evaluation Division
401 M Street, S.W.
Washington, D.C. 20460

Submitted by:

Science Applications International Corporation
8400 Westpark Drive
McLean, Virginia 22102

EPA Contract No. 68-03-3453, Work Assignment 1-6
SAIC Project No. 1-813-07-521-06

September 6, 1988

SAIC

CONTENTS

Page

1. INTRODUCTION 1-1
  1.1 Background and Purpose. 1-1
  1.2 Incinerator Descriptions. 1-7
2. DATA BASE DOCUMENTATION. 2-1
3. INDIVIDUAL STUDY NOTES AND DATA LISTINGS 3-1
4. SUBSETTING THE DATA BASE FOR DESCRIPTIVE STATISTICS. 4-1
5. SUMMARY STATISTICS 5-1

APPENDIX

A-1 Lognormal Probability Plots of Mean Destruction Efficiencies A-1-1
A-2 Lognormal Probability Plots of Mean Emission Rates A-2-1

LIST OF TABLES

Page

TABLE 1. STUDIES REVIEWED FOR DATA BASE DEVELOPMENT. 1-2
TABLE 2. COMPARISON OF STUDIES 1-4
TABLE 3. METALS COVERED BY STUDY 1-6
TABLE 4. COMPARISON OF INCINERATORS. 1-9
TABLE 5. DATA BASE CODING SHEET. 2-2
TABLE R1. COMPILED DATA FOR REFERENCE 1. 3-3
TABLE R2. COMPILED DATA FOR REFERENCE 2. 3-6
TABLE R3. COMPILED DATA FOR REFERENCE 3. 3-9
TABLE R4. COMPILED DATA FOR REFERENCE 4. 3-13
TABLE R5. COMPILED DATA FOR REFERENCE 5. 3-15
TABLE R6. COMPILED DATA FOR REFERENCE 6. 3-20
TABLE R7. COMPILED DATA FOR REFERENCE 7. 3-24

LIST OF TABLES (Continued)

Page

TABLE R8. COMPILED DATA FOR REFERENCE 8. 3-26

TABLE R9. COMPILED DATA FOR REFERENCE 9. 3-30

TABLE R10. COMPILED DATA FOR REFERENCE 10. 3-34

TABLE R11. COMPILED DATA FOR REFERENCE 11. 3-36

TABLE R12. COMPILED DATA FOR REFERENCE 12. 3-40

TABLE R13. COMPILED DATA FOR REFERENCE 13. 3-42

TABLE R14. COMPILED DATA FOR REFERENCE 14. 3-45

TABLE R15. COMPILED DATA FOR REFERENCE 15. 3-48

TABLE R16. COMPILED DATA FOR REFERENCE 16. 3-50

TABLE 6. OBSERVATIONS OMITTED FROM THE DATA BASE SUBSET. 4-2

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS. 4-3

TABLE 8. DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES BY INCINERATOR WITHIN REFERENCE DOCUMENT. 5-5

TABLE 9. DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES WITHIN REFERENCE DOCUMENT. 5-13

TABLE 10. DESCRIPTIVE STATISTICS ON MEAN INCINERATOR REMOVAL EFFICIENCIES ACROSS INCINERATOR AND REFERENCE DOCUMENT. . 5-18

1. INTRODUCTION

1.1 Background and Purpose

The U.S. Environmental Protection Agency (EPA) is required, under Section 405(d) of the Clean Water Act, to develop regulations for the use and disposal of sewage sludge. The development of these regulations requires the identification of toxic pollutants of concern in sewage sludge and the setting of criteria, for levels of selected pollutants, specific to and consistent with sludge use or disposal options.

The disposal option of concern here is sewage sludge incineration. The objectives of this exercise are to construct a data base on the fractions of metals present in the sludge feed that are emitted to the atmosphere after incineration, and to produce statistical summaries of these data. This report documents the data base construction and methods used to calculate summary statistics.

A data base was developed using information contained in 16 incinerator studies, depicting a range of operating conditions for multiple hearth and fluidized bed sewage sludge incinerators. The data base contains sludge feed and particle emission rates, metal loading and emission rates, and scrubber efficiencies by incinerator. Because the studies differed in scope and purpose, the quantity of data varied with respect to the number of incinerators visited, the number of metals analyzed, the number of sample runs, and whether scrubber efficiencies were measured. A list of the 16 studies reviewed is presented in Table 1 and a comparison of these studies is given in Table 2. Table 3 contains the metals contaminants covered in the individual studies.

The data base was developed to provide estimates of metal destruction efficiencies as a function of the levels of metals in the feed. The data will be used to determine sludge metal concentrations that could result in incinerator stack emissions which could pose a threat to human health. The studies used incinerators performing in the field. Thus, the standards developed using these studies will reflect field conditions.

TABLE 1. STUDIES REVIEWED FOR DATA BASE DEVELOPMENT

Study Reference Number	Study
1.	White, M. and G. Beluzo, GCA Corporation, Performance Tests and Material Balance for a Fluidized-Bed Sludge Incinerator, November, 1980.
2.	Wall, H. and J. Farrell, Municipal Environmental Research Laboratory, U.S. EPA, "Particulate Emissions from Municipal Wastewavter Sludge Incinerators," Presented at Mid-Atlantic States Section, Air Pollution Control Association, Newark, New Jersey, April 27, 1979.
3.	Copeland, B.J., "A Study of Heavy Metal Emissions from Fluidized Bed Incinerators," Proceedings of the 30th Industrial Waste Conference, May 6, 7, and 8, 1975. Ann Arbor Science, pp. 78-79, 1977.
4.	Greenberg, R.R., W.H. Zeller, and G.E. Gordon, "Atmospheric Emissions of Elements of Particles from the Parkway Sewage Sludge Incinerator." Environmental Science and Technology, 15.64 (1981).
5.	Bennett, R.L., K.T. Knapp, and D.L. Duke, "Chemical and Physical Characterization of Municipal Sludge Incinerator Emissions." NTIS No. PB 84-169325, March 1984.
6.	U.S. EPA, Sewage Sludge Incineration, EPA R-2-77-040, August 1972.
7.	Devling, R.T., R.M. Manganelli, and G.T. Baer, Fate and Behavior of Selected Heavy Metals in Incinerated Sludge, Journal Water Pollution Control Federation 52(10), 2552-2557.
8.	Adams, R.C., L.E. Keller, and E.V. Robb, Radian Corporation, "Particulate Removal Capability of a Baghouse Filter on the Exhaust of a Multiple Hearth Furnace Burning Sewage Sludge," Draft, September 30, 1985. EPA WERL, EPA No. 68-03-3148.
9.	Adams, R.C., G. Bockol, J.A. Maddox, and E.V. Robb, Radian Corporation, "Particulate Removal Evaluation of an Electrostatic Precipitator Dust Removal System Installed on a Multiple Hearth Incinerator Burning Sewage Sludge," Draft, U.S. EPA WERL, September 30, 1985, EPA No. 68-03-3148.
10.	Klinger, W.A., TRC Environmental Consultants, Biological Sludge Incinerator Air Impacts Study, Arlington County Department of Public Works, March 28, 1986.
11.	Farrell, J.B. and H. Wall, "Ultimate Disposal Section, Municipal Environmental Research Laboratory, Air Pollution Discharges from Ten Sewage Sludge Incinerators." Revision No. 1: Draft Review Copy, February 5, 1981.

TABLE 1. STUDIES REVIEWED FOR DATA BASE DEVELOPMENT
(Continued)

Study Reference Number	Study
12.	U.S. EPA, Emission Measurement Branch, Method Development and Testing for Chromium Sewage Sludge Incinerator NO. 13. Detroit Water and Sewer Department, Detroit, Michigan, August 1986.
13.	Knisley, D.R., Lamb, L.M., Smith, A.M., Radian Corporation, "Site 1 Draft Emission Test Report Sewage Sludge Test Program," U.S. EPA, WERL, July 17, 1987, EPA No. 68-02-6999, Work Assignment No. 57.
14.	Knisley, D.R., Barnett, K.W., Holder, D.J., Radian Corporation, "Site 2 Draft Emission Test Report Sewage Sludge Test Program," Volume I: Emission Test Results, U.S. EPA, WERL, October 19, 1987, EPA No. 68-02-6999, Work Assignment No. 71.
15.	Knisley, D.R., Barnett, K.W., Holder, D.J., Radian Corporation, "Site 3 Draft Emission Test Report Sewage Sludge Test Program," U.S. EPA, WERL, October 1, 1987, EPA No. 68-02-6999, Work Assignment No. 60.
16.	Knisley, D.R., Barnett, K.W., Palozzolo, M.A., Radian Corporation, "Site 4 Draft Final Emission Test Report Sewage Sludge Test Program," Volumes I & II: Emission Test Results, U.S. EPA, WERL, May 9, 1988, EPA No. 68-02-6999, Work Assignment No. 71.

TABLE 2. COMPARISON OF STUDIES

Study Ref. No.	Number & Type of Furnace	Number & Type of Scrubber	No. of Metals Evaluated	Scrubber Efficiency	Test Method	Number of Samples per Furnace
1	1 F.B.	Venturi and tray	7	No	SASS and MM5	3
2	7 MH 1 F.B.	3 Impingement 4 Venturi and impingement 1 Wet cyclone	4	Yes	SASS	1
3	3 F.B.	2 Wet Venturi and packed tower 1 Venturi and impingement	8	No	M5	6 3 1
4	1 F.B.	Venturi and packed tower	27	No	M5	5*
5	3 MH 1 F.B.	1 Cyclone 3 Tray	25	Yes	M5	45-95*
6	2 MH 1 F.B.	2 Impingement 1 Inertial jet	15	No	Other	3 1
7	1 F.B.	Impingement	7	No	M5	3
8	MH	Cyclone and Venturi and impingement	24	Yes	SASS	3
9	MH	Cyclone and Venturi and impingement	24	Yes	SASS	3
10	1 MH	Wet scrubber	3	No	MM5	7
11	7 MH 2 F.B.	1 Cyclone 4 Venturi and impingement 4 Impingement	9	Yes	SASS	1
12	1 MH	Impingement	1	Yes	M5	4
13	1 MH	Impingement	6	No	M12	4** 3***

TABLE 2. COMPARISON OF STUDIES
(Continued)

Study Ref. No.	Number & Type of Furnace	Number & Type of Scrubber	No. of Metals Evaluated	Scrubber Efficiency	Test Method	Number of Samples per Furnace
14	1 MH	Venturi and Impingement	6	Yes	M12	4** 3***
15	1 FB	Venturi and Impingement	6	No	M12	3
16	1 MH	Venturi and Impingement	8	Yes	M12	11

*Analysis reported as aggregates.
**Samples based on 4 runs under steady state conditions.
***Samples based on 3 runs under normal operating conditions.

MH - Multiple Hearth Incinerator
FB - Fluidized Bed Incinerator
SASS - Source Assessment Sampling System for particulates
M5 - EPA Method 5 for particulates
MM5 - Modified EPA Method 5 for particulates
M12 - EPA Method 12 for particulates

TABLE 3. METALS COVERED BY STUDY

Element		Study Reference Number															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Aluminum	(AL)				●	●			●	●							
Antimony	(Sb)				●	●			●	●							
Arsenic	(As)	●		●			●		●	●				●	●	●	●
Barium	(Ba)				●	●			●	●							
Beryllium	(Be)						●							●	●	●	●
Bromine	(Br)				●	●											
Cadmium	(Cd)	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●
Calcium	(Ca)				●	●			●	●							
Cerium	(Ce)				●												
Cesium	(Cs)				●												
Chlorine	(Cl)				●	●											
Chromium	(Cr)	●		●	●	●	●	●	●	●		●	●	●	●	●	
Cobalt	(Co)				●	●	●		●	●							
Copper	(Cu)	●		●	●	●	●	●	●	●		●					●
Europium	(Eu)				●												
Gold	(Au)								●	●							
Indium	(In)				●												
Iron	(Fe)		●		●	●	●		●	●		●					
Lead	(Pb)	●	●	●	●	●	●	●	●	●	●	●		●	●	●	●
Magnesium	(Mg)				●	●			●	●							
Manganese	(Mn)				●	●	●		●	●		●					
Mercury	(Hg)			●			●	●			●						
Nickel	(Ni)	●	●			●	●	●	●	●		●		●	●	●	●
Phosphorus	(P)					●			●	●							
Potassium	(K)					●											
Scandium	(Sc)				●												
Selenium	(Se)				●	●			●	●							●
Silicon	(Si)					●											
Silver	(Ag)			●	●		●		●	●		●					
Sodium	(Na)				●	●			●	●							
Strontium	(Sr)						●										
Sulfur	(S)					●			●	●							
Tantalum	(Ta)				●												
Tin	(Sn)					●			●	●							
Titanium	(Ti)				●	●			●	●							
Vanadium	(V)				●	●	●		●	●							
Ytterbium	(Yb)				●												
Zinc	(Zn)	●		●	●	●	●	●	●	●		●					●

1.2 Incinerator Descriptions

The data base was constructed using emissions data for multiple hearth and fluidized bed incinerators. The two incinerator types chosen for inclusion comprise the bulk of sludge incineration facilities in operation. Of the 156 sludge incinerators in operation in 1985, 120 were multiple hearth facilities and 25 were fluidized beds.* Electric, rotary kiln, and cocombustion technologies accounted for the remaining 11 units.

The multiple hearth incinerator is a counter-current vertical combustor. The furnace is a cylindrical shell divided into 6 to 12 hearths. In the center of the furnace is a rotating shaft with rabble arms attached to each hearth level. The sludge enters the top of the furnace where it is spread, mixed, and moved to an opening to the next (lower) hearth by the rabble arms. Combustion air enters the bottom of the furnace and flows in the opposite direction that the sludge takes. As the sludge moves down through the furnace it passes through three zones: the drying, combustion, and cooling zones. In the drying zone, the sludge is heated and dried by hot combustion gases. The sludge is burned in the combustion zone. In the cooling zone, the hot sludge ash is used to warm the combustion air that enters the furnace. The ash discharges through the bottom of the furnace. The flue gases, which exit the top of the furnace, are sent to the scrubber.

The fluidized bed incinerator is also a vertical cylinder furnace. Instead of being divided into multiple hearths, the fluidized bed incinerator contains a single chamber with a sandbed. The sandbed is "fluidized" by combustion air passing through the bottom of the sandbed, resulting in good mixing of sand, air, and sludge. The sludge ash, which is less dense than the sand, is carried out of the furnace with the flue gases. The larger ash particles are collected in a Venturi scrubber. Smaller particulates and gaseous pollutants are controlled by a secondary, wet scrubber.

---

*U.S. EPA, Municipal Wastewater Sludge Combustion Technology, Technology Transfer, EPA/625/4-85/015, September 1985.

Data from 28 incinerators were included in the data base. Of the 28 facilities included, 20 are multiple hearth incinerators and 8 are fluidized beds. A list of incinerators identifying the incinerator type, air pollution device(s) used, and study coverage is presented in Table 4. The facility was identified by name in References 1, 3, 4, 6, 7, 8, 9, 10, and 12. References 2, 5, 11, 13, 14, 15, and 16 identified the incinerators by code only. The air pollution control device (or scrubber) was specified for 27 of the 28 incinerators. The incinerator type was identified for all of the facilities. More detailed information is provided in the study notes presented in Section 3.

TABLE 4. COMPARISON OF INCINERATORS

Incinerator ID	Incinerator Type	Air Pollution Control Device	Study	Facility
1	FB	VI	R1	Port Washington Waste Water Treatment Facility, NY
2	MH	I	R2, R11	Incinerator A
3	MH	I	R2, R11	Incinerator C
4	MH	I	R2, R11	Incinerator D
5	MH	VI	R2, R11	Incinerator E
6	MH	VI	R2, R11	Incinerator F
7	MH	VI	R2	Incinerator H
8	FB	VI	R2, R11	Incinerator J
9	MH	C	R2, R11	Incinerator K
10	FB	VP	R3, R4	Parkway Incinerator, MD
11	FB	VT	R3	Downingtown, PA
12	FB	VI	R3, R6	Barstow, CA
13	MH	I	R5	Incinerator O
14	MH	I	R5	Incinerator P
15	FB	I	R5	Incinerator Q
16	MH	C	R5	Incinerator R
17	MH	I	R6	Tahoe Incinerator, CA
18	MH	J	R6	Lorton Incinerator, VA
19	FB	VI	R7	Northwest Bergen Sewer Authority, NJ
20	MH	VCI	R8, R9	Norfolk, VA
21	MH	?	R10	Arlington, VA

TABLE 4. COMPARISON OF INCINERATORS
(Continued)

Incinerator ID	Incinerator Type	Air Pollution Control Device	Study	Facility
22	MH	I	R11	Incinerator B
23	MH	VI	R11	Incinerator G
24	MH	I	R12	Detroit Municipal Wastewater Treatment Plant, MI
25	MH	I	R13	Site 1
26	MH	VI	R14	Site 2
27	FB	VI	R15	Site 3
28	MH	VI	R16	Site 4

MH - Multiple Hearth Incinerator
FB - Fluidized Bed Incinerator
V - Venturi
I - Impingement
C - Cyclone
P - Packed Tower
C - Cooling Tower
J - Inertial Jet

2. DATA BASE DOCUMENTATION

Data were taken from 16 incinerator studies for the development of the data base. Each study was reviewed to determine:

- The type and number of incinerators sampled
- The type of scrubber used for each incinerator
- The sampling method employed
- The number of samples taken per incinerator
- The metals chosen for analysis
- The operating condition of the incinerators
- The analysis and presentation of results.

The data were compiled from the studies and converted to units appropriate for statistical analysis. The sludge feed rate was converted to a dry basis with units of kg/hr. The particulate emission rate was also converted to kg/hr. Metal feed and emission rates were converted to mg/hr. Two references (#2 and #6) could not be presented in this manner. Reference #2 presented the metal emissions data directly in terms of percent feed, thereby eliminating the need to calculate destruction efficiency. Reference #6 presented concentration data for metals in both the feed and emissions, and sludge feed and particulate emission rates. However, the concentration data values did not correspond to the feed and emission rates. Thus, the concentration units were retained for Reference 6.

The data were reviewed to determine which information elements were suitable for inclusion as variables in the data base. After choosing the variables, the data were coded into the data base. Table 5 provides definitions for the variables encoded in the data base.

The individual observations that constitute the data base are listed by Study in Chapter 3. Notes on each study indicating the location of the data in the original study reference and describing the extraction of the data from the study references are also provided.

TABLE 5. DATA BASE CODING SHEET

Variable	Description
AIR POLL CONTROL DEVICE	The type of air pollution control device (or scrubber) associated with a given incinerator. Six scrubber types were identified in the studies. The scrubbers may be used individually or in combination. The scrubber types are identified by the following codes: V - Venturi I - Impingement C - Cyclone P - Packed Tower T - Cooling Tower J - Internal Jet
EMISS	The emission measurement associated with a particular pollutant. The quantity of pollutant that exits in the incinerator stack.
EMISS UNIT	The units associated with the emission measurement. The units are usually presented in terms of mass per unit time. The possibilities include: KG/H - Kilograms per hour MG/H - Milligrams per hour MG/G - Milligrams per gram of particulate % - Percent of feed.
FEED	The feed measurement associated with a particular pollutant. The quantity of pollutant that enters the incinerator. The feed rate is given on a dry basis. The scrubber efficiency, defined as the mass reduction percentage, is also placed in this column. The scrubber efficiency is only associated with the pollutant code SCRUBBER.
FEED UNIT	The units associated with the feed measurement. The units are usually presented in terms of mass (dry basis) per unit time. Possibilities include: KG/H - Kilograms per hour MG/H - Milligrams per hour MG/G - Milligrams per gram of feed % - The scrubber efficiency, defined as the percentage of the particulates removed on a mass basis.

TABLE 5. DATA BASE CODING SHEET
(Continued)

Variable	Description
INCIN ID	A code which is used to identify the incinerator from which the measurement was obtained. A list of incinerators by incinerator ID number is provided in Table 4.
INCIN TYPE	The type of incinerator asssociated with a particular observation. Possibilities include: FB - Fluidized Bed Incinerator MH - Multiple Hearth Incinerator.
METHOD	The particulate sampling method. Possibilities include: M5 - EPA Method 5 MM5 - A modified version of EPA Method 5 SASS - Source Assessment Sampling System M12 - EPA Method 12.
PART	The particulate emission rate in units of kilograms per hour. The particulate emission rate appears only with observations involving a chemical species.
POLLUTANT	The subject of the measurement. The variable identifies not only pollutants, but also whether the sludge feed rate, the particulate emission rate, or the scrubber efficiency is associated with a particular observation.
REF	The reference number which identifies the study from which the observation was obtained. A list of references by reference number is provided in Table 1.
SAMPLE ID	The sample identity number. A number of observations will be associated with each sample ID. The sample ID is used to separate groups of samples taken as a single set from other sample groups associated with a particular incinerator within a given study.

TABLE 5. DATA BASE CODING SHEET
(Continued)

Variable	Description
SLUDGE	The sludge feed rate (dry basis) in units of kilograms per hour. The sludge feed rate appears only with observations involving a chemical species.
TEMP	The combustion temperature in degrees Celsius. The highest temperature reported if multiple hearth temperatures are given.
YEAR	The year that the samples were taken. If this date is not reported, the date that the results were first published is used.

3. INDIVIDUAL STUDY NOTES AND DATA LISTINGS

1. White, M. and G. Beluzo, GCA Corporation, Performance of Emissions Tests and Material Balance for a Fluidized-Bed Sludge Incinerator, Final Report, EPA Contract No. 68-01-4143, November 1980.

   The data also appear in the following document:

   Trichon, M., R.T. Devling, P.F. Fennelly, and M.O. White, "The Fate of Trace Metals in a Fluidized Bed Sewage Sludsge Incinerator." [Undated Draft Document]

   The data were drawn from the latter document. The sludge feed rates were obtained from Table 2 (p. 4). The particulate emissions were obtained from Table 5 (p. 6) and the particulate metal concentrations were obtained from Table 6 (p. 6).

   Modified Method 5 (MM5) and Source Assessment Sampling System (SASS) were used to measure particulate emissions. Both the SASS and MM5 sets of data are presented.

   Essentially, the same data appear in the GCA document. The dry sludge feed rates and particulate emission rates may be obtained from Tables 7 and 8 (p. 4). The particulate metal concentrations may be obtained from Table 12 (p. 28). The metal feed rates may be calculated using the metal concentrations obtained from Table 15 (p. 30).

TABLE R1. COMPILED DATA FOR REFERENCE 1

-- REF=R1 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	71	MG/H	0.43	704	MM5	FB	1	VI	1	1980	182.9	0.031
CADMIUM	MG/H	732	MG/H	0.07	704	MM5	FB	1	VI	1	1980	182.9	0.031
CHROMIUM	MG/H	8488	MG/H	ND	704	MM5	FB	1	VI	1	1980	182.9	0.031
COPPER	MG/H	168296	MG/H	94	704	MM5	FB	1	VI	1	1980	182.9	0.031
NICKEL	MG/H	5488	MG/H	ND	704	MM5	FB	1	VI	1	1980	182.9	0.031
LEAD	MG/H	42094	MG/H	0.13	704	MM5	FB	1	VI	1	1980	182.9	0.031
ZINC	MG/H	120734	MG/H	ND	704	MM5	FB	1	VI	1	1980	182.9	0.031
ARSENIC	MG/H	71	MG/H	0.36	704	SASS	FB	1	VI	2	1980	182.9	0.009
CADMIUM	MG/H	732	MG/H	1.0	704	SASS	FB	1	VI	2	1980	182.9	0.009
CHROMIUM	MG/H	8488	MG/H	7.3	704	SASS	FB	1	VI	2	1980	182.9	0.009
COPPER	MG/H	168296	MG/H	64	704	SASS	FB	1	VI	2	1980	182.9	0.009
NICKEL	MG/H	5488	MG/H	ND	704	SASS	FB	1	VI	2	1980	182.9	0.009
LEAD	MG/H	42074	MG/H	28	704	SASS	FB	1	VI	2	1980	182.9	0.009
ZINC	MG/H	120734	MG/H	ND	704	SASS	FB	1	VI	2	1980	182.9	0.009
ARSENIC	MG/H	49	MG/H	2.2	816	MM5	FB	1	VI	3	1980	212	0.055
CADMIUM	MG/H	849	MG/H	32.5	816	MM5	FB	1	VI	3	1980	212	0.055
CHROMIUM	MG/H	6364	MG/H	ND	816	MM5	FB	1	VI	3	1980	212	0.055
COPPER	MG/H	178188	MG/H	372	816	MM5	FB	1	VI	3	1980	212	0.055
NICKEL	MG/H	4242	MG/H	ND	816	MM5	FB	1	VI	3	1980	212	0.055
LEAD	MG/H	44546	MG/H	249	816	MM5	FB	1	VI	3	1980	212	0.055
ZINC	MG/H	137883	MG/H	ND	816	MM5	FB	1	VI	3	1980	212	0.055
ARSENIC	MG/H	49	MG/H	0.33	816	SASS	FB	1	VI	4	1980	212	0.007
CADMIUM	MG/H	849	MG/H	7.0	816	SASS	FB	1	VI	4	1980	212	0.007
CHROMIUM	MG/H	6364	MG/H	7.0	816	SASS	FB	1	VI	4	1980	212	0.007
COPPER	MG/H	178188	MG/H	139	816	SASS	FB	1	VI	4	1980	212	0.007
NICKEL	MG/H	4242	MG/H	ND	816	SASS	FB	1	VI	4	1980	212	0.007
LEAD	MG/H	44546	MG/H	112	816	SASS	FB	1	VI	4	1980	212	0.007
ZINC	MG/H	137883	MG/H	58	816	SASS	FB	1	VI	4	1980	212	0.007
ARSENIC	MG/H	64	MG/H	7.4	927	MM5	FB	1	VI	5	1980	236	0.076
CADMIUM	MG/H	945	MG/H	169	927	MM5	FB	1	VI	5	1980	236	0.076
CHROMIUM	MG/H	7089	MG/H	ND	927	MM5	FB	1	VI	5	1980	236	0.076
COPPER	MG/H	226855	MG/H	847	927	MM5	FB	1	VI	5	1980	236	0.076
NICKEL	MG/H	4726	MG/H	ND	927	MM5	FB	1	VI	5	1980	236	0.076
LEAD	MG/H	47261	MG/H	3704	927	MM5	FB	1	VI	5	1980	236	0.076
ZINC	MG/H	146510	MG/H	180	927	MM5	FB	1	VI	5	1980	236	0.076

TABLE R1. COMPILED DATA FOR REFERENCE 1

-- REF=R1 --
(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	64	MG/H	1.1	927	SASS	FB	1	VI	6	1980	236	0.045
CADMIUM	MG/H	945	MG/H	382	927	SASS	FB	1	VI	6	1980	236	0.045
CHROMIUM	MG/H	7089	MG/H	47	927	SASS	FB	1	VI	6	1980	236	0.045
COPPER	MG/H	226855	MG/H	2450	927	SASS	FB	1	VI	6	1980	236	0.045
NICKEL	MG/H	4726	MG/H	ND	927	SASS	FB	1	VI	6	1980	236	0.045
LEAD	MG/H	47261	MG/H	3633	927	SASS	FB	1	VI	6	1980	236	0.045
ZINC	MG/H	146510	MG/H	495	927	SASS	FB	1	VI	6	1980	236	0.045

2. Wall, H. and Farrell, Municipal Environmental Research Laboratory, U.S. EPA, "Particulate Emissions from Municipal Wastewater Sludge Incinerators," presented at Mid-Atlantic States Section, Air Pollution Control Association, Newark, New Jersey, April 27, 1979.

Sampling was accomplished using a high volume Source Assessment Sampling System (SASS) train. Ten incinerators were sampled of which 8 have metal emissions data.

Sludge feed rates and particulate emission rates were obtained from Tables 2 and 3 (p. 6). The percentage of metal constituents in feed that leave the scrubber data were obtained from Table 4 (p. 7).

The concentrations of the metals were not given for the feed and the particulates separately. The percentages of the metals in the feed that were emitted to the atmosphere were reported. The raw data from which these percentages were calculated were not reported.

The data gathered for the generation of this report were also used in Reference #11.

TABLE R2. COMPILED DATA FOR REFERENCE 2

REF=R2

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
CADMIUM			%	29.4		SASS	MH	2	I	1	1979	1280	0.92
IRON			%	0.006		SASS	MH	2	I	1	1979	1280	0.92
NICKEL			%	0.38		SASS	MH	2	I	1	1979	1280	0.92
LEAD			%	3.8		SASS	MH	2	I	1	1979	1280	0.92
SCRUBBER	%	83					MH	2	I	1	1979	1280	0.92
CADMIUM			%	35.9		SASS	MH	3	I	1	1979	2443	1.6
IRON			%	0.02		SASS	MH	3	I	1	1979	2443	1.6
NICKEL			%	0.14		SASS	MH	3	I	1	1979	2443	1.6
LEAD			%	3.5		SASS	MH	3	I	1	1979	2443	1.6
SCRUBBER	%	92					MH	3	I	1	1979	2443	1.6
CADMIUM			%	14.2		SASS	MH	4	I	1	1979	2711	2.0
IRON			%	0.05		SASS	MH	4	I	1	1979	2711	2.0
NICKEL			%	0.35		SASS	MH	4	I	1	1979	2711	2.0
LEAD			%	13.8		SASS	MH	4	I	1	1979	2711	2.0
SCRUBBER	%	99					MH	4	I	1	1979	2711	2.0
CADMIUM			%	9.1		SASS	MH	5	VI	1	1979	1597	0.21
IRON			%	0.01		SASS	MH	5	VI	1	1979	1597	0.21
NICKEL			%	0.12		SASS	MH	5	VI	1	1979	1597	0.21
LEAD			%	4.5		SASS	MH	5	VI	1	1979	1597	0.21
SCRUBBER	%	93					MH	5	VI	1	1979	1597	0.21
CADMIUM			%	6.0		SASS	MH	6	VI	1	1979	936	0.55
IRON			%	4.16		SASS	MH	6	VI	1	1979	936	0.55
NICKEL			%	0.08		SASS	MH	6	VI	1	1979	936	0.55
LEAD			%	5.6		SASS	MH	6	VI	1	1979	936	0.55
SCRUBBER	%	93				SASS	MH	6	VI	1	1979	936	0.55
CADMIUM			%	16.0		SASS	MH	7	VI	1	1979	640	0.56
IRON			%	0.12		SASS	MH	7	VI	1	1979	640	0.56
NICKEL			%	0.28		SASS	MH	7	VI	1	1979	640	0.56
LEAD			%	14.7		SASS	MH	7	VI	1	1979	640	0.56
SCRUBBER	%	96				SASS	MH	7	VI	1	1979	640	0.56
CADMIUM			%	0		SASS	FB	8	VI	1	1979	1340	0.048
IRON			%	0.02		SASS	FB	8	VI	1	1979	1340	0.048
NICKEL			%	1.1		SASS	FB	8	VI	1	1979	1340	0.048
LEAD			%	0		SASS	FB	8	VI	1	1979	1340	0.048
SCRUBBER	%	97				SASS	FB	8	VI	1	1979	1340	0.048

TABLE R2. COMPILED DATA FOR REFERENCE 2

-- REF=R2 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
CADMIUM			%	14.7		SASS	MH	9	C	1	1979	778	4.6
IRON			%	0.40		SASS	MH	9	C	1	1979	778	4.6
NICKEL			%	1.5		SASS	MH	9	C	1	1979	778	4.6
LEAD			%	16.9		SASS	MH	9	C	1	1979	778	4.6
SCRUBBER	%	78				SASS	MH	9	C	1	1979	778	4.6

3. Copeland, B.J., "A Study of Heavy Metal Emissions from Fluidized Bed Incinerators," Proceedings of the 30th Industrial Waste Conference, May 6, 7, and 8, 1975. Ann Arbor Science, pp. 78-89, 1977.

Data were reported for three fluidized bed incinerators. The data presented for the Barstow incinerator appear to have been extracted from Reference #6.

Sludge feed rates were not specified to be on either a wet or dry basis. A dry basis is assumed since this makes the Barstow incinerator's feed data correspond to Reference #6. EPA Method 5 was used in this study.

The Parkway incinerator data appear in Table 2 (pp. 82-83) and Table 3 (pp. 84-85). The Downingtown incinerator data appear in Table 4 (p. 86). The Barstow data appear in Table 5 (p. 87).

TABLE R3. COMPILED DATA FOR REFERENCE 3

-- REF=R3 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
LEAD	MG/H	34609	MG/H	126	760	M5	FB	10	VP	1	1974	853	0.140
CHROMIUM	MG/H	14742	MG/H	108	760	M5	FB	10	VP	1	1974	853	0.140
ARSENIC	MG/H	ND	MG/H	ND	760	M5	FB	10	VP	1	1974	853	0.140
MERCURY	MG/H	ND	MG/H		760	M5	FB	10	VP	1	1974	853	0.140
CADMIUM	MG/H	4264	MG/H	238	760	M5	FB	10	VP	1	1974	853	0.140
COPPER	MG/H	103012	MG/H	166	760	M5	FB	10	VP	1	1974	853	0.140
SILVER	MG/H	363	MG/H	ND	760	M5	FB	10	VP	1	1974	853	0.140
ZINC	MG/H	986301	MG/H	185	760	M5	FB	10	VP	1	1974	853	0.140
LEAD	MG/H	25311	MG/H	20	760	M5	FB	10	VP	2	1974	623	0.079
CHROMIUM	MG/H	10750	MG/H	4	760	M5	FB	10	VP	2	1974	623	0.079
ARSENIC	MG/H	ND	MG/H	0.005	760	M5	FB	10	VP	2	1974	623	0.079
MERCURY	MG/H	ND	MG/H		760	M5	FB	10	VP	2	1974	623	0.079
CADMIUM	MG/H	3130	MG/H	1	760	M5	FB	10	VP	2	1974	623	0.079
COPPER	MG/H	75252	MG/H	10	760	M5	FB	10	VP	2	1974	623	0.079
SILVER	MG/H	272	MG/H	ND	760	M5	FB	10	VP	2	1974	623	0.079
ZINC	MG/H	720448	MG/H	19	760	M5	FB	10	VP	2	1974	623	0.079
LEAD	MG/H	22090	MG/H	8	760	M5	FB	10	VP	3	1974	544	0.079
CHROMIUM	MG/H	9389	MG/H	9	760	M5	FB	10	VP	3	1974	544	0.079
ARSENIC	MG/H	ND	MG/H	ND	760	M5	FB	10	VP	3	1974	544	0.079
MERCURY	MG/H	907285	MG/H		760	M5	FB	10	VP	3	1974	544	0.079
CADMIUM	MG/H	2722	MG/H	21	760	M5	FB	10	VP	3	1974	544	0.079
COPPER	MG/H	65726	MG/H	35	760	M5	FB	10	VP	3	1974	544	0.079
SILVER	MG/H	227	MG/H	ND	760	M5	FB	10	VP	3	1974	544	0.079
ZINC	MG/H	629230	MG/H	34	760	M5	FB	10	VP	3	1974	544	0.079
LEAD	MG/H	6350	MG/H	114	760	M5	FB	10	VP	4	1974	336	0.142
CHROMIUM	MG/H	12701	MG/H	31	760	M5	FB	10	VP	4	1974	336	0.142
ARSENIC	MG/H	ND	MG/H	ND	760	M5	FB	10	VP	4	1974	336	0.142
MERCURY	MG/H	ND	MG/H	375	760	M5	FB	10	VP	4	1974	336	0.142
CADMIUM	MG/H	1361	MG/H	41	760	M5	FB	10	VP	4	1974	336	0.142
COPPER	MG/H	64411	MG/H	71	760	M5	FB	10	VP	4	1974	336	0.142
SILVER	MG/H	3175	MG/H	ND	760	M5	FB	10	VP	4	1974	366	0.142
ZINC	MG/H	137440	MG/H	98	760	M5	FB	10	VP	4	1974	366	0.142
LEAD	MG/H	67586	MG/H	594	760	M5	FB	10	VP	5	1974	481	0.160
CHROMIUM	MG/H	18144	MG/H	215	760	M5	FB	10	VP	5	1974	481	0.160
ARSENIC	MG/H	ND	MG/H	0.02	760	M5	FB	10	VP	5	1974	481	0.160

TABLE R3. COMPILED DATA FOR REFERENCE 3

REF=R3

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
MERCURY	MG/H	ND	MG/H	544	760	M5	FB	10	VP	5	1974	481	0.160
CADMIUM	MG/H	1814	MG/H	15	760	M5	FB	10	VP	5	1974	481	0.160
COPPER	MG/H	92080	MG/H	75	760	M5	FB	10	VP	5	1974	481	0.160
SILVER	MG/H	4717	MG/H	0.008	760	M5	FB	10	VP	5	1974	481	0.160
ZINC	MG/H	197315	MG/H	147	760	M5	FB	10	VP	5	1974	481	0.160
LEAD	MG/H	51256	MG/H	490	760	M5	FB	10	VP	6	1974	366	0.175
CHROMIUM	MG/H	13608	MG/H	30	760	M5	FB	10	VP	6	1974	366	0.175
ARSENIC	MG/H	ND	MG/H	ND	760	M5	FB	10	VP	6	1974	366	0.175
MERCURY	MG/H	ND	MG/H		760	M5	FB	10	VP	6	1974	366	0.175
CADMIUM	MG/H	1361	MG/H	32	760	M5	FB	10	VP	6	1974	366	0.175
COPPER	MG/H	69854	MG/H	102	760	M5	FB	10	VP	6	1974	366	0.175
SILVER	MG/H	3629	MG/H	ND	760	M5	FB	10	VP	6	1974	366	0.175
ZINC	MG/H	149687	MG/H	170	760	M5	FB	10	VP	6	1974	366	0.175
LEAD	MG/H	80287	MG/H	649	766	M5	FB	11	VT	1	1974	203	0.076
CHROMIUM	MG/H	33113	MG/H	517	766	M5	FB	11	VT	1	1974	203	0.076
ARSENIC	MG/H	5443	MG/H	ND	766	M5	FB	11	VT	1	1974	203	0.076
MERCURY	MG/H	367	MG/H	74	766	M5	FB	11	VT	1	1974	203	0.076
CADMIUM	MG/H	6804	MG/H	27	766	M5	FB	11	VT	1	1974	203	0.076
COPPER	MG/H	159666	MG/H	18	766	M5	FB	11	VT	1	1974	203	0.076
SILVER	MG/H	2722	MG/H	5	766	M5	FB	11	VT	1	1974	203	0.076
ZINC	MG/H	125646	MG/H	649	766	M5	FB	11	VT	1	1974	203	0.076
LEAD	MG/H	11567	MG/H	308	760	MM5	FB	12	VI	1	1971	231	0.255
CHROMIUM	MG/H	115667	MG/H	151	760	MM5	FB	12	VI	1	1971	231	0.255
ARSENIC	MG/H		MG/H		760	MM5	FB	12	VI	1	1971	231	0.255
MERCURY	MG/H	1270	MG/H		760	MM5	FB	12	VI	1	1971	231	0.255
CADMIUM	MG/H	134174	MG/H	29	760	MM5	FB	12	VI	1	1971	231	0.255
COPPER	MG/H	393269	MG/H	625	760	MM5	FB	12	VI	1	1971	231	0.255
SILVER	MG/H		MG/H		760	MM5	FB	12	VI	1	1971	231	0.255
ZINC	MG/H	323868	MG/H	750	760	MM5	FB	12	VI	2	1971	215	0.348
LEAD	MG/H	10750	MG/H	117	760	MM5	FB	12	VI	2	1971	215	0.348
CHROMIUM	MG/H	107502	MG/H	151	760	MM5	FB	12	VI	2	1971	215	0.348
ARSENIC	MG/H		MG/H		760	MM5	FB	12	VI	2	1971	215	0.348
MERCURY	MG/H	1179	MG/H		760	MM5	FB	12	VI	2	1971	215	0.348
CADMIUM	MG/H	124694	MG/H	33	760	MM5	FB	12	VI	2	1971	215	0.348

TABLE R3. COMPILED DATA FOR REFERENCE 3

-------------------- REF=R3 --------------------

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
COPPER	MG/H	365508	MG/H	709	760	MM5	FB	12	VI	2	1971	215	0.348
SILVER	MG/H		MG/H		760	MM5	FB	12	VI	2	1971	215	0.348
ZINC	MG/H	301007	MG/H	3125	760	MM5	FB	12	VI	2	1971	215	0.348
LEAD	MG/H	9163	MG/H	279	760	MM5	FB	12	VI	3	1971	183	0.260
CHROMIUM	MG/H	91400	MG/H	188	760	MM5	FB	12	VI	3	1971	183	0.260
ARSENIC	MG/H		MG/H		760	MM5	FB	12	VI	3	1971	183	0.260
MERCURY	MG/H	998	MG/H		760	MM5	FB	12	VI	3	1971	183	0.260
CADMIUM	MG/H	106006	MG/H	29	760	MM5	FB	12	VI	3	1971	183	0.260
COPPER	MG/H	310759	MG/H	792	760	MM5	FB	12	VI	3	1971	183	0.260
SILVER	MG/H		MG/H		760	MM5	FB	12	VI	3	1971	183	0.260
ZINC	MG/H	255919	MG/H	3750	760	MM5	FB	12	VI	3	1971	183	0.260

4. Greenberg, R.R., W.H. Zeller, and G.E. Gordon, "Atmospheric Emissions of Elements of Particles from the Parkway Sewage Sludge Incinerator." Environmental Science and Technology, Vol. 15, No. 1, pp. 64-70 (1981).

The Parkway incinerator consists of two identical fluidized bed reactor systems each capable of incinerating from 540 to 610 kg of dry sludge per hour. Venturi and secondary wet scrubbers are used. The type of secondary scrubber (e.g., plate, packed bed, etc.) is not specified in this document; however, Reference #3 identifies the secondary scrubber as a packed tower type.

The emissions data provided are averages of five individual measurements collected using EPA Method 5. The average emissions and standard deviations are reported; the individual measurements are not provided.

Table I (pg. 65) was used to generate the hourly constituent feed rates. A 600 kg/hr dry sludge feed rate was assumed (p. 70).

Table VII (pg. 69) was used to generate the hourly constituent emission rates. The daily rate was converted to an hourly rate using a 24-hour workday. A 24-hour workday was assumed by the authors to compute daily emissions.

The study does not report the date that the samples were collected.

TABLE R4. COMPILED DATA FOR REFERENCE 4

-- REF=R4 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SODIUM	MG/H	440000	MG/H	342	760	MM5	FB	10	VP	1	1981		
CAESIUM	MG/H	306	MG/H	0.050	760	MM5	FB	10	VP	1	1981	600	
MAGNESIUM	MG/H	1500000	MG/H	198	760	MM5	FB	10	VP	1	1981	600	
CALCIUM	MG/H	27600000	MG/H	2700	760	MM5	FB	10	VP	1	1981	600	
BARIUM	MG/H	426000	MG/H	306	760	MM5	FB	10	VP	1	1981	600	
CHLORINE	MG/H	540000	MG/H	90	760	MM5	FB	10	VP	1	1981	600	
BROMINE	MG/H	30000	MG/H	29	760	MM5	FB	10	VP	1	1981	600	
ALUMINUM	MG/H	17400000	MG/H	648	760	MM5	FB	10	VP	1	1981	600	
SCANDIUM	MG/H	1140	MG/H	0.042	760	MM5	FB	10	VP	1	1981	600	
TITANIUM	MG/H	1260000	MG/H	69	760	MM5	FB	10	VP	1	1981	600	
VANADIUM	MG/H	15000	MG/H	3.7	760	MM5	FB	10	VP	1	1981	600	
CHROMIUM	MG/H	78000	MG/H	5.9	760	MM5	FB	10	VP	1	1981	600	
MANGANESE	MG/H	780000	MG/H	15	760	MM5	FB	10	VP	1	1981	600	
IRON	MG/H	24600000	MG/H	1530	760	MM5	FB	10	VP	1	1981	600	
COBALT	MG/H	10200	MG/H	0.75	760	MM5	FB	10	VP	1	1981	600	
COPPER	MG/H	300000	MG/H	35	760	MM5	FB	10	VP	1	1981	600	
ZINC	MG/H	576000	MG/H	64	760	MM5	FB	10	VP	1	1981	600	
SELENIUM	MG/H	1140	MG/H	6.0	760	MM5	FB	10	VP	1	1981	600	
SILVER	MG/H	17400	MG/H	7.2	760	MM5	FB	10	VP	1	1981	600	
CADMIUM	MG/H	7200	MG/H	7.3	760	MM5	FB	10	VP	1	1981	600	
INDIUM	MG/H	ND	MG/H	0.008	760	MM5	FB	10	VP	1	1981	600	
ANTIMONY	MG/H	2640	MG/H	1.2	760	MM5	FB	10	VP	1	1981	600	
CERIUM	MG/H	18000	MG/H	3.5	760	MM5	FB	10	VP	1	1981	600	
EUROPIUM	MG/H	228	MG/H	0.018	760	MM5	FB	10	VP	1	1981	600	
YTTERBIUM	MG/H	360	MG/H	0.360	760	MM5	FB	10	VP	1	1981	600	
TANTALUM	MG/H	258	MG/H	0.003	760	MM5	FB	10	VP	1	1981	600	
LEAD	MG/H	258000	MG/H	82	760	MM5	FB	10	VP	1	1981	600	

5. Bennett, R.L., K.T. Knapp, and D.L. Duke, Emission Measurement and Characterization Division, Environmental Sciences Research Laboratory, "Chemical and Physical Characterization of Municipal Sludge Incinerator Emissions." NTIS No. PB 84-169325, March 1984.

Four incinerators were tested. Three were multiple hearth facilities and one was a fluidized bed.

Metal levels given as mean concentrations were obtained from Table 5 (p. 27). The individual samples were not reported in the study; from 45 to 95 samples were averaged for each value reported (p. 19). All data are reported on a dry basis. Feed data were obtained from Table 1 (p. 3).

All emissions data are based on particulate matter. No vapor levels were measured. Particulate emissions data were obtained from Table 8 (p. 30). Scrubber efficiencies were calculated on a mass basis from data obtained from Tables 14, 15, and 17 (pp. 39-42). The scrubber efficiency for the fluidized bed could not be determined since the scrubber inlet was not sampled.

TABLE R5. COMPILED DATA FOR REFERENCE 5

REF=R5

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	99.7			733	M5	MH	13	I	1	1979		
SODIUM	MG/H	19400000	MG/H	24564	733	M5	MH	13	I	1	1979	1940	0.89
MAGNESIUM	MG/H	34920000	MG/H	6319	733	M5	MH	13	I	1	1979	1940	0.89
ALUMINUM	MG/H	65960000	MG/H	9078	733	M5	MH	13	I	1	1979	1940	0.89
SILICON	MG/H	195940000	MG/H	41741	733	M5	MH	13	I	1	1979	1940	0.89
PHOSPHORUS	MG/H	124160000	MG/H	41741	733	M5	MH	13	I	1	1979	1940	0.89
SULFUR	MG/H	18042000	MG/H	46725	733	M5	MH	13	I	1	1979	1940	0.89
CHLORINE	MG/H	8730000	MG/H	16020	733	M5	MH	13	I	1	1979	1940	0.89
POTASSIUM	MG/H	25220000	MG/H	15219	733	M5	MH	13	I	1	1979	1940	0.89
CALCIUM	MG/H	329800000	MG/H	55180	733	M5	MH	13	I	1	1979	1940	0.89
TITANIUM	MG/H	16296000	MG/H	1958	733	M5	MH	13	I	1	1979	1940	0.89
VANADIUM	MG/H	582000	MG/H	2492	733	M5	MH	13	I	1	1979	1940	0.89
CHROMIUM	MG/H	4268000	MG/H	6853	733	M5	MH	13	I	1	1979	1940	0.89
MANGANESE	MG/H	13580000	MG/H	1869	733	M5	MH	13	I	1	1979	1940	0.89
IRON	MG/H	129980000	MG/H	25899	733	M5	MH	13	I	1	1979	1940	0.89
COBALT	MG/H	194000	MG/H	ND	733	M5	MH	13	I	1	1979	1940	0.89
NICKEL	MG/H	582000	MG/H	ND	733	M5	MH	13	I	1	1979	1940	0.89
COPPER	MG/H	2328000	MG/H	ND	733	M5	MH	13	I	1	1979	1940	0.89
ZINC	MG/H	5820000	MG/H	57316	733	M5	MH	13	I	1	1979	1940	0.89
SELENIUM	MG/H	ND	MG/H		733	M5	MH	13	I	1	1979	1940	0.89
BROMINE	MG/H	ND	MG/H		733	M5	MH	13	I	1	1979	1940	0.89
CADMIUM	MG/H	388000	MG/H	2937	733	M5	MH	13	I	1	1979	1940	0.89
TIN	MG/H	5820000	MG/H	12638	733	M5	MH	13	I	1	1979	1940	0.89
ANTIMONY	MG/H	582000	MG/H	445	733	M5	MH	13	I	1	1979	1940	0.89
BARIUM	MG/H	4850000	MG/H	712	733	M5	MH	13	I	1	1979	1940	0.89
LEAD	MG/H	6596000	MG/H	36223	733	M5	MH	13	I	1	1979	1940	0.89
SCRUBBER	%	87.2			643	M5	MH	14	I	1	1979		
SODIUM	MG/H	12180000	MG/H	16986	643	M5	MH	14	I	1	1979	1740	2.98
MAGNESIUM	MG/H	17400000	MG/H	25628	643	M5	MH	14	I	1	1979	1740	2.98
ALUMINUM	MG/H	62640000	MG/H	90890	643	M5	MH	14	I	1	1979	1740	2.98
SILICON	MG/H	226200000	MG/H	242274	643	M5	MH	14	I	1	1979	1740	2.98
PHOSPHORUS	MG/H	76560000	MG/H	100128	643	M5	MH	14	I	1	1979	1740	2.98
SULFUR	MG/H	22620000	MG/H	53640	643	M5	MH	14	I	1	1979	1740	2.98
CHLORINE	MG/H	1392000	MG/H	7748	643	M5	MH	14	I	1	1979	1740	2.98
POTASSIUM	MG/H	19140000	MG/H	26522	643	M5	MH	14	I	1	1979	1740	2.98

TABLE R5. COMPILED DATA FOR REFERENCE 5

REF=R5

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
CALCIUM	MG/H	107880000	MG/H	151682	643	M5	MH	14	I	1	1979	1740	2.98
TITANIUM	MG/H	13224000	MG/H	26224	643	M5	MH	14	I	1	1979	1740	2.98
VANADIUM	MG/H	696000	MG/H	2086	643	M5	MH	14	I	1	1979	1740	2.98
CHROMIUM	MG/H	8700000	MG/H	28012	643	M5	MH	14	I	1	1979	1740	2.98
MANGANESE	MG/H	4002000	MG/H	4768	643	M5	MH	14	I	1	1979	1740	2.98
IRON	MG/H	295800000	MG/H	409750	643	M5	MH	14	I	1	1979	1740	2.98
COBALT	MG/H	522000	MG/H	1490	643	M5	MH	14	I	1	1979	1740	2.98
NICKEL	MG/H	2436000	MG/H	7152	643	M5	MH	14	I	1	1979	1740	2.98
COPPER	MG/H	13050000	MG/H	47084	643	M5	MH	14	I	1	1979	1740	2.98
ZINC	MG/H	19140000	MG/H	106684	643	M5	MH	14	I	1	1979	1740	2.98
SELENIUM	MG/H	ND	MG/H	1192	643	M5	MH	14	I	1	1979	1740	2.98
BROMINE	MG/H	ND	MG/H	3278	643	M5	MH	14	I	1	1979	1740	2.98
CADMIUM	MG/H	696000	MG/H	2086	643	M5	MH	14	I	1	1979	1740	2.98
TIN	MG/H	4350000	MG/H	71222	643	M5	MH	14	I	1	1979	1740	2.98
ANTIMONY	MG/H	348000	MG/H	1490	643	M5	MH	14	I	1	1979	1740	2.98
BARIUM	MG/H	7134000	MG/H	16688	643	M5	MH	14	I	1	1979	1740	2.98
LEAD	MG/H	8352000	MG/H	67646	643	M5	MH	14	I	1	1979	1740	2.98
SCRUBBER	%				787	M5	FB	15	I	1	1979		
SODIUM	MG/H	ND	MG/H	1842	787	M5	FB	15	I	1	1979	838	0.094
MAGNESIUM	MG/H	7290600	MG/H	949	787	M5	FB	15	I	1	1979	838	0.094
ALUMINUM	MG/H	33520000	MG/H	2886	787	M5	FB	15	I	1	1979	838	0.094
SILICON	MG/H	142460000	MG/H	5010	787	M5	FB	15	I	1	1979	838	0.094
PHOSPHORUS	MG/H	34358000	MG/H	3892	787	M5	FB	15	I	1	1979	838	0.094
SULFUR	MG/H	6871600	MG/H	13555	787	M5	FB	15	I	1	1979	838	0.094
CHLORINE	MG/H	ND	MG/H	874	787	M5	FB	15	I	1	1979	838	0.094
POTASSIUM	MG/H	10056000	MG/H	1006	787	M5	FB	15	I	1	1979	838	0.094
CALCIUM	MG/H	62850000	MG/H	8234	787	M5	FB	15	I	1	1979	838	0.094
TITANIUM	MG/H	6452600	MG/H	611	787	M5	FB	15	I	1	1979	838	0.094
VANADIUM	MG/H	251400	MG/H	169	787	M5	FB	15	I	1	1979	838	0.094
CHROMIUM	MG/H	1843600	MG/H	263	787	M5	FB	15	I	1	1979	838	0.094
MANGANESE	MG/H	2849200	MG/H	432	787	M5	FB	15	I	1	1979	838	0.094
IRON	MG/H	63688000	MG/H	4249	787	M5	FB	15	I	1	1979	838	0.094
COBALT	MG/H	83800	MG/H	ND	787	M5	FB	15	I	1	1979	838	0.094
NICKEL	MG/H	502800	MG/H	ND	787	M5	FB	15	I	1	1979	838	0.094

TABLE R5. COMPILED DATA FOR REFERENCE 5

------------------------------------ REF=R5 ------------------------------------

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
COPPER	MG/H	2262600	MG/H	263	787	M5	FB	15	I	1	1979	838	0.094
ZINC	MG/H	8380000	MG/H	1617	787	M5	FB	15	I	1	1979	838	0.094
SELENIUM	MG/H	ND	MG/H	338	787	M5	FB	15	I	1	1979	838	0.094
BROMINE	MG/H	ND	MG/H	724	787	M5	FB	15	I	1	1979	838	0.094
CADMIUM	MG/H	670400	MG/H	122	787	M5	FB	15	I	1	1979	838	0.094
TIN	MG/H	2095000	MG/H	555	787	M5	FB	15	I	1	1979	838	0.094
ANTIMONY	MG/H	83800	MG/H	ND	787	M5	FB	15	I	1	1979	838	0.094
BARIUM	MG/H	3771000	MG/H	376	787	M5	FB	15	I	1	1979	838	0.094
LEAD	MG/H	4944200	MG/H	2124	787	M5	FB	15	I	1	1979	838	0.094
SCRUBBER	%	94.9				M5	MH	16	C	1	1980		
SODIUM	MG/H	ND	MG/H	7242		M5	MH	16	C	1	1980	1890	2.13
MAGNESIUM	MG/H	17388000	MG/H	639		M5	MH	16	C	1	1980	1890	2.13
ALUMINUM	MG/H	98280000	MG/H	1065		M5	MH	16	C	1	1980	1890	2.13
SILICON	MG/H	226800000	MG/H	19383		M5	MH	16	C	1	1980	1890	2.13
PHOSPHORUS	MG/H	69930000	MG/H	17892		M5	MH	16	C	1	1980	1890	2.13
SULFUR	MG/H	8883000	MG/H	81579		M5	MH	16	C	1	1980	1890	2.13
CHLORINE	MG/H	12852000	MG/H	61983		M5	MH	16	C	1	1980	1890	2.13
POTASSIUM	MG/H	20790000	MG/H	3834		M5	MH	16	C	1	1980	1890	2.13
CALCIUM	MG/H	185220000	MG/H	4899		M5	MH	16	C	1	1980	1890	2.13
TITANIUM	MG/H	22302000	MG/H	426		M5	MH	16	C	1	1980	1890	2.13
VANADIUM	MG/H	ND	MG/H	ND		M5	MH	16	C	1	1980	1890	2.13
CHROMIUM	MG/H	7182000	MG/H	7029		M5	MH	16	C	1	1980	1890	2.13
MANGANESE	MG/H	2079000	MG/H	213		M5	MH	16	C	1	1980	1890	2.13
IRON	MG/H	102060000	MG/H	7242		M5	MH	16	C	1	1980	1890	2.13
COBALT	MG/H	189000	MG/H	ND		M5	MH	16	C	1	1980	1890	2.13
NICKEL	MG/H	1134000	MG/H	ND		M5	MH	16	C	1	1980	1890	2.13
COPPER	MG/H	8316000	MG/H	16401		M5	MH	16	C	1	1980	1890	2.13
ZINC	MG/H	26460000	MG/H	57297		M5	MH	16	C	1	1980	1890	2.13
SELENIUM	MG/H	ND	MG/H	852		M5	MH	16	C	1	1980	1890	2.13
BROMINE	MG/H	ND	MG/H	5538		M5	MH	16	C	1	1980	1890	2.13
CADMIUM	MG/H	567000	MG/H	59001		M5	MH	16	C	1	1980	1890	2.13
TIN	MG/H	3591000	MG/H	24708		M5	MH	16	C	1	1980	1890	2.13
ANTIMONY	MG/H	189000	MG/H	1278		M5	MH	16	C	1	1980	1890	2.13

TABLE R5. COMPILED DATA FOR REFERENCE 5

-- REF=R5 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
BARIUM	MG/H	5103000	MG/H	426		M5	MH	16	C	1	1980	1890	2.13
LEAD	MG/H	4347000	MG/H	66882		M5	MH	16	C	1	1980	1890	2.13

6. U.S. EPA Task Force, "Sewage Sludge Incineration," EPA R-2-77-040, August 1972 (NTIS No. PB 211 323).

Emissions tested for 3 facilities. Emissions testing performed at a later date than sludge feed testing. Mass balances for sludge feed and particulate emissions do not correspond directly to particulate metal testing.

Particulate and feed mass flows were obtained from Tables 2 to 4 (pp. 16-18). Sludge metals concentrations were obtained from Table 8 (p. 32). Concentration of metals in particulates were obtained from Table 10 (p. 34).

Mercury emissions were not measured. Assumed by authors to be 100 percent through stack.

Inlet (feed) concentrations of PCBs and pesticides measured (Table 7, p. 31). One-hundred percent destruction assumed since no PCBs or pesticides were found in particulates, ash, or scrubber effluent.

Zinc contamination in particulates due to Zn from glass fiber filter.

TABLE R6. COMPILED DATA FOR REFERENCE 6

-------------------- REF=R6 --------------------

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SILVER	MG/G	0.05	MG/G	0.05		MM5	FB	12	VI	1	1971		
ARSENIC	MG/G		MG/G	ND		MM5	FB	12	VI	1	1971		
BERYLLIUM	MG/G	ND	MG/G	0.0005		MM5	FB	12	VI	1	1971		
CADMIUM	MG/G	0.58	MG/G	0.1		MM5	FB	12	VI	1	1971		
COBALT	MG/G	ND	MG/G			MM5	FB	12	VI	1	1971		
CHROMIUM	MG/G	0.5	MG/G	0.5		MM5	FB	12	VI	1	1971		
COPPER	MG/G	1.7	MG/G	2.0		MM5	FB	12	VI	1	1971		
IRON	MG/G	10.6	MG/G	5.0		MM5	FB	12	VI	1	1971		
MANGANESE	MG/G	0.18	MG/G	0.1		MM5	FB	12	VI	1	1971		
NICKEL	MG/G	ND	MG/G	ND		MM5	FB	12	VI	1	1971		
LEAD	MG/G	0.8	MG/G	1.0		MM5	FB	12	VI	1	1971		
STRONTIUM	MG/G	ND	MG/G	0.2		MM5	FB	12	VI	1	1971		
VANADIUM	MG/G	2.1	MG/G	ND		MM5	FB	12	VI	1	1971		
ZINC	MG/G	1.4	MG/G	2.3		MM5	FB	12	VI	1	1971		
MERCURY	MG/G	0.0055				MM5	FB	12	VI	1	1971		
SILVER			MG/G				FB	12	VI	2	1971		
ARSENIC			MG/G	ND			FB	12	VI	2	1971		
BERYLLIUM			MG/G	0.0005			FB	12	VI	2	1971		
CADMIUM			MG/G	0.08			FB	12	VI	2	1971		
COBALT			MG/G	0.4			FB	12	VI	2	1971		
CHROMIUM			MG/G	0.4			FB	12	VI	2	1971		
COPPER			MG/G	1.8			FB	12	VI	2	1971		
IRON			MG/G	12			FB	12	VI	2	1971		
MANGANESE			MG/G	0.1			FB	12	VI	2	1971		
NICKEL			MG/G	0.05			FB	12	VI	2	1971		
LEAD			MG/G	0.3			FB	12	VI	2	1971		
STRONTIUM			MG/G				FB	12	VI	2	1971		
VANADIUM			MG/G	ND			FB	12	VI	2	1971		
ZINC			MG/G	8			FB	12	VI	2	1971		
SILVER			MG/G			MM5	FB	12	VI	3	1971		
ARSENIC			MG/G	ND		MM5	FB	12	VI	3	1971		
BERYLLIUM			MG/G	0.0005		MM5	FB	12	VI	3	1971		
CADMIUM			MG/G	0.1		MM5	FB	12	VI	3	1971		
COBALT			MG/G	0.05		MM5	FB	12	VI	3	1971		
CHROMIUM			MG/G	0.6		MM5	FB	12	VI	3	1971		

TABLE R6. COMPILED DATA FOR REFERENCE 6

------------------------------ REF=R6 ------------------------------
(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
COPPER			MG/G	2.5		MM5	FB	12	VI	3	1971		
IRON			MG/G	16		MM5	FB	12	VI	3	1971		
MANGANESE			MG/G	0.2		MM5	FB	12	VI	3	1971		
NICKEL			MG/G	0.1		MM5	FB	12	VI	3	1971		
LEAD			MG/G	0.9		MM5	FB	12	VI	3	1971		
STRONTIUM			MG/G			MM5	FB	12	VI	3	1971		
VANADIUM			MG/G	0.1		MM5	FB	12	VI	3	1971		
ZINC			MG/G	12		MM5	FB	12	VI	3	1971		
SILVER	MG/G	0.27	MG/G	0.2		MM5	MH	17	I	1	1971		
ARSENIC	MG/G		MG/G	ND		MM5	MH	17	I	1	1971		
BERYLLIUM	MG/G	ND	MG/G	0.001		MM5	MH	17	I	1	1971		
CADMIUM	MG/G	0.18	MG/G	1.0		MM5	MH	17	I	1	1971		
COBALT	MG/G	ND	MG/G	4.0		MM5	MH	17	I	1	1971		
CHROMIUM	MG/G	1.0	MG/G	1.0		MM5	MH	17	I	1	1971		
COPPER	MG/G	1.3	MG/G	1.0		MM5	MH	17	I	1	1971		
IRON	MG/G	8.7	MG/G	4.0		MM5	MH	17	I	1	1971		
MANGANESE	MG/G	0.6	MG/G	0.5		MM5	MH	17	I	1	1971		
NICKEL	MG/G	ND	MG/G	0.4		MM5	MH	17	I	1	1971		
LEAD	MG/G	2.8	MG/G	20		MM5	MH	17	I	1	1971		
STRONTIUM	MG/G	0.51	MG/G	0.4		MM5	MH	17	I	1	1971		
VANADIUM	MG/G	ND	MG/G	ND		MM5	MH	17	I	1	1971		
ZINC	MG/G	1.6	MG/G	40		MM5	MH	17	I	1	1971		
MERCURY	MG/G	0.0045				MM5	MH	17	I	1	1971		
SILVER			MG/G			MM5	MH	17	I	2	1971		
ARSENIC			MG/G	ND		MM5	MH	17	I	2	1971		
BERYLLIUM			MG/G	0.0005		MM5	MH	17	I	2	1971		
CADMIUM			MG/G	1.0		MM5	MH	17	I	2	1971		
COBALT			MG/G	0.05		MM5	MH	17	I	2	1971		
CHROMIUM			MG/G	0.1		MM5	MH	17	I	2	1971		
COPPER			MG/G	0.04		MM5	MH	17	I	2	1971		
IRON			MG/G	28		MM5	MH	17	I	2	1971		
MANGANESE			MG/G	0.4		MM5	MH	17	I	2	1971		
NICKEL			MG/G	0.2		MM5	MH	17	I	2	1971		
LEAD			MG/G	7		MM5	MH	17	I	2	1971		

TABLE R6. COMPILED DATA FOR REFERENCE 6

REF=R6

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
STRONTIUM			MG/G			MM5	MH	17	I	2	1971		
VANADIUM			MG/G	ND		MM5	MH	17	I	2	1971		
ZINC			MG/G	50		MM5	MH	17	I	2	1971		
SILVER			MG/G			MM5	MH	17	I	3	1971		
ARSENIC			MG/G	ND		MM5	MH	17	I	3	1971		
BERYLLIUM			MG/G	0.0005		MM5	MH	17	I	3	1971		
CADMIUM			MG/G	1.5		MM5	MH	17	I	3	1971		
COBALT			MG/G	0.3		MM5	MH	17	I	3	1971		
CHROMIUM			MG/G	0.4		MM5	MH	17	I	3	1971		
COPPER			MG/G	0.8		MM5	MH	17	I	3	1971		
IRON			MG/G	11		MM5	MH	17	I	3	1971		
MANGANESE			MG/G	0.3		MM5	MH	17	I	3	1971		
NICKEL			MG/G	0.3		MM5	MH	17	I	3	1971		
LEAD			MG/G	15		MM5	MH	17	I	3	1971		
STRONTIUM			MG/G			MM5	MH	17	I	3	1971		
VANADIUM			MG/G	ND		MM5	MH	17	I	3	1971		
ZINC			MG/G	55		MM5	MH	17	I	3	1971		
SILVER	MG/G	ND	MG/G			MM5	MH	18	J	1	1971		
ARSENIC	MG/G		MG/G			MM5	MH	18	J	1	1971		
BERYLLIUM	MG/G	ND	MG/G	ND		MM5	MH	18	J	1	1971		
CADMIUM	MG/G	0.17	MG/G	ND		MM5	MH	18	J	1	1971		
COBALT	MG/G	ND	MG/G	0.05		MM5	MH	18	J	1	1971		
CHROMIUM	MG/G	0.4	MG/G	0.5		MM5	MH	18	J	1	1971		
COPPER	MG/G	0.9	MG/G	1.3		MM5	MH	18	J	1	1971		
IRON	MG/G	27.4	MG/G	17		MM5	MH	18	J	1	1971		
MANGANESE	MG/G	0.5	MG/G	0.4		MM5	MH	18	J	1	1971		
NICKEL	MG/G	ND	MG/G	2.0		MM5	MH	18	J	1	1971		
LEAD	MG/G	1.1	MG/G	9.0		MM5	MH	18	J	1	1971		
STRONTIUM	MG/G	ND	MG/G			MM5	MH	18	J	1	1971		
VANADIUM	MG/G	ND	MG/G	ND		MM5	MH	18	J	1	1971		
ZINC	MG/G	0.4	MG/G	19		MM5	MH	18	J	1	1971		
MERCURY	MG/G	0.003				MM5	MH	18	J	1	1971		

7. Devling, R.T., R.M. Manganelli, and G.T.Baer, "Fate and Behavior of Selected Heavy Metals in Incinerated Sludge," Journal Water Pollution Control Federation 52(10), 2552-2557 (October 1980).

Feed and emission rates for Zn, Cu, Pb, Cr, Ni, and Cd were obtained from Table II (p. 2555). Data were normalized to mg/hr.

Mercury rates were not presented in the same format. Figure 2 presents a mercury mass balance. Due to matrix interference, a feed rate of 8197 mg per day was used by the authors to determine the percent weight distribution in Table IV. This number was used to calculate the hourly feed rate.

Sludge feed rates are reported for each sampling period in Table I. The input (g/period) column most likely gives the feed rates on a dry basis, but this is not explicitly stated. Particulate rates were not given.

The sampling date was not provided in the study. The date used in the data base (1980) is the publication date.

TABLE R7. COMPILED DATA FOR REFERENCE 7

--- REF=R7 ---

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ZINC	MG/H	174000	MG/H	ND	788	M5	FB	19	VI	1	1980		
COPPER	MG/H	126500	MG/H	125	788	M5	FB	19	VI	1	1980		
LEAD	MG/H	37550	MG/H	100	788	M5	FB	19	VI	1	1980		
CHROMIUM	MG/H	4600	MG/H	50	788	M5	FB	19	VI	1	1980		
NICKEL	MG/H	3075	MG/H	7.5	788	M5	FB	19	VI	1	1980		
CADMIUM	MG/H	525	MG/H	0.5	788	M5	FB	19	VI	1	1980		
ZINC	MG/H	137250	MG/H	ND	788	M5	FB	19	VI	2	1980		
COPPER	MG/H	104750	MG/H	25	788	M5	FB	19	VI	2	1980		
LEAD	MG/H	28175	MG/H	20	788	M5	FB	19	VI	2	1980		
CHROMIUM	MG/H	4075	MG/H	25	788	M5	FB	19	VI	2	1980		
NICKEL	MG/H	2900	MG/H	7.5	788	M5	FB	19	VI	2	1980		
CADMIUM	MG/H	325	MG/H	ND	788	M5	FB	19	VI	2	1980		
ZINC	MG/H	154178	MG/H	ND	788	M5	FB	19	VI	3	1980		
COPPER	MG/H	117511	MG/H	44	788	M5	FB	19	VI	3	1980		
LEAD	MG/H	33867	MG/H	89	788	M5	FB	19	VI	3	1980		
CHROMIUM	MG/H	3911	MG/H	18	788	M5	FB	19	VI	3	1980		
NICKEL	MG/H	2800	MG/H	ND	788	M5	FB	19	VI	3	1980		
CADMIUM	MG/H	489	MG/H	ND	788	M5	FB	19	VI	3	1980		
MERCURY	MG/H	800	MG/H	780	788	MM5	FB	19	VI	4	1980		

8. Adams, R.C., L.E. Keller, and E.V. Robb, Radian Corporation, "Particulate Removal Capability of a Baghouse Filter on the Exhaust of a Multiple Hearth Furnace Burning Sewage Sludge," Draft, September 30, 1985. EPA Water Engineering Research Laboratory, EPA Contract No. 68-03-3148.

The object of the study is a multiple hearth (6 hearths) incinerator with two cyclones, a Venturi, and an impingement scrubber in series. The study compared this configuration with a pilot-scale baghouse filter. The data for the normal (scrubber) operation only are used. The baghouse filter was only a pilot-scale operation and at the time of the study there were no sludge incineration facilities using this technology. For these reasons the baghouse filter data were omitted.

The feed rates were obtained from Table 2-1 (p. 2-2). The particulate emission rates were obtained from Table 2-9 (p. 2-13) and the scrubber particulate efficiencies from Table 2-12 (p. 2-15). The metal feed rates were calculated from metal concentrations presented in Table 2-5 (p. 2-5). The metal emission rates were calculated using particulate metal concentrations obtained from tables 2.1S, 3.1S, and 4.1S (p. A-13, A-17, and A-21).

The Source Assessment Sampling System (SASS) protocol was followed for particulate sampling.

TABLE R8. COMPILED DATA FOR REFERENCE 8

-- REF=R8 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	91.9			768	SASS	MH	20	VCI	1	1984		
ALUMINUM	MG/H		MG/H	6671	768	SASS	MH	20	VCI	1	1984	283	0.109
ANTIMONY	MG/H		MG/H	74	768	SASS	MH	20	VCI	1	1984	283	0.109
ARSENIC	MG/H		MG/H	65	768	SASS	MH	20	VCI	1	1984	283	0.109
BARIUM	MG/H		MG/H	39	768	SASS	MH	20	VCI	1	1984	283	0.109
CADMIUM	MG/H		MG/H	2409	768	SASS	MH	20	VCI	1	1984	283	0.109
CALCIUM	MG/H		MG/H	666	768	SASS	MH	20	VCI	1	1984	283	0.109
CHROMIUM	MG/H		MG/H	164	768	SASS	MH	20	VCI	1	1984	283	0.109
COBALT	MG/H		MG/H	1066	768	SASS	MH	20	VCI	1	1984	283	0.109
COPPER	MG/H		MG/H	681	768	SASS	MH	20	VCI	1	1984	283	0.109
GOLD	MG/H		MG/H	ND	768	SASS	MH	20	VCI	1	1984	283	0.109
IRON	MG/H		MG/H	1384	768	SASS	MH	20	VCI	1	1984	283	0.109
LEAD	MG/H		MG/H	1199	768	SASS	MH	20	VCI	1	1984	283	0.109
MAGNESIUM	MG/H		MG/H	541	768	SASS	MH	20	VCI	1	1984	283	0.109
MANGANESE	MG/H		MG/H	35	768	SASS	MH	20	VCI	1	1984	283	0.109
NICKEL	MG/H		MG/H	102	768	SASS	MH	20	VCI	1	1984	283	0.109
PHOSPHORUS	MG/H		MG/H	1363	768	SASS	MH	20	VCI	1	1984	283	0.109
SELENIUM	MG/H		MG/H	97	768	SASS	MH	20	VCI	1	1984	283	0.109
SILVER	MG/H		MG/H	32	768	SASS	MH	20	VCI	1	1984	283	0.109
SODIUM	MG/H		MG/H	1537	768	SASS	MH	20	VCI	1	1984	283	0.109
SULFUR	MG/H		MG/H	34662	768	SASS	MH	20	VCI	1	1984	283	0.109
TIN	MG/H		MG/H	413	768	SASS	MH	20	VCI	1	1984	283	0.109
TITANIUM	MG/H		MG/H	62	768	SASS	MH	20	VCI	1	1984	283	0.109
VANADIUM	MG/H		MG/H	379	768	SASS	MH	20	VCI	1	1984	283	0.109
ZINC	MG/H		MG/H	3292	768	SASS	MH	20	VCI	1	1984	283	0.109
SCRUBBER	%	95.8			761	SASS	MH	20	VCI	2	1984		
ALUMINUM	MG/H	123728	MG/H	1228	761	SASS	MH	20	VCI	2	1984	209	0.074
ANTIMONY	MG/H	40337	MG/H	47	761	SASS	MH	20	VCI	2	1984	209	0.074
ARSENIC	MG/H	126236	MG/H	19	761	SASS	MH	20	VCI	2	1984	209	0.074
BARIUM	MG/H	12247	MG/H	99	761	SASS	MH	20	VCI	2	1984	209	0.074
CADMIUM	MG/H	45562	MG/H	730	761	SASS	MH	20	VCI	2	1984	209	0.074
CALCIUM	MG/H	11453200	MG/H	1236	761	SASS	MH	20	VCI	2	1984	209	0.074
CHROMIUM	MG/H	72314	MG/H	414	761	SASS	MH	20	VCI	2	1984	209	0.074
COBALT	MG/H	7461	MG/H	ND	761	SASS	MH	20	VCI	2	1984	209	0.074
COPPER	MG/H	988570	MG/H	347	761	SASS	MH	20	VCI	2	1984	209	0.074

TABLE R8. COMPILED DATA FOR REFERENCE 8

-- REF=R8 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
GOLD	MG/H	1116	MG/H	ND	761	SASS	MH	20	VCI	2	1984	209	0.074
IRON	MG/H	13543200	MG/H	1739	761	SASS	MH	20	VCI	2	1984	209	0.074
LEAD	MG/H	130625	MG/H	317	761	SASS	MH	20	VCI	2	1984	209	0.074
MAGNESIUM	MG/H	3971000	MG/H	372	761	SASS	MH	20	VCI	2	1984	209	0.074
MANGANESE	MG/H	66462	MG/H	52	761	SASS	MH	20	VCI	2	1984	209	0.074
NICKEL	MG/H	29887	MG/H	537	761	SASS	MH	20	VCI	2	1984	209	0.074
PHOSPHORUS	MG/H	13668600	MG/H	689	761	SASS	MH	20	VCI	2	1984	209	0.074
SELENIUM	MG/H	159049	MG/H	69	761	SASS	MH	20	VCI	2	1984	209	0.074
SILVER	MG/H	ND	MG/H	12	761	SASS	MH	20	VCI	2	1984	209	0.074
SODIUM	MG/H	1406570	MG/H	8140	761	SASS	MH	20	VCI	2	1984	209	0.074
SULFUR	MG/H	4598000	MG/H	15910	761	SASS	MH	20	VCI	2	1984	209	0.074
TIN	MG/H	51205	MG/H	87	761	SASS	MH	20	VCI	2	1984	209	0.074
TITANIUM	MG/H	1540330	MG/H	37	761	SASS	MH	20	VCI	2	1984	209	0.074
VANADIUM	MG/H	96558	MG/H	122	761	SASS	MH	20	VCI	2	1984	209	0.074
ZINC	MG/H	1270720	MG/H	1317	761	SASS	MH	20	VCI	2	1984	209	0.074
SCRUBBER	%	95.1			748	SASS	MH	20	VCI	3	1984		
ALUMINUM	MG/H	159517	MG/H	12852	748	SASS	MH	20	VCI	3	1984	269	0.084
ANTIMONY	MG/H	58373	MG/H	51	748	SASS	MH	20	VCI	3	1984	269	0.084
ARSENIC	MG/H	149026	MG/H	68	748	SASS	MH	20	VCI	3	1984	269	0.084
BARIUM	MG/H	24318	MG/H	30	748	SASS	MH	20	VCI	3	1984	269	0.084
CADMIUM	MG/H	63753	MG/H	2100	748	SASS	MH	20	VCI	3	1984	269	0.084
CALCIUM	MG/H	14526000	MG/H	2428	748	SASS	MH	20	VCI	3	1984	269	0.084
CHROMIUM	MG/H	104103	MG/H	204	748	SASS	MH	20	VCI	3	1984	269	0.084
COBALT	MG/H	10222	MG/H	ND	748	SASS	MH	20	VCI	3	1984	269	0.084
COPPER	MG/H	1229330	MG/H	701	748	SASS	MH	20	VCI	3	1984	269	0.084
GOLD	MG/H	1167	MG/H	ND	748	SASS	MH	20	VCI	3	1984	269	0.084
IRON	MG/H	16920100	MG/H	1445	748	SASS	MH	20	VCI	3	1984	269	0.084
LEAD	MG/H	188569	MG/H	1260	748	SASS	MH	20	VCI	3	1984	269	0.084
MAGNESIUM	MG/H	5595200	MG/H	87	748	SASS	MH	20	VCI	3	1984	269	0.084
MANGANESE	MG/H	87694	MG/H	62	748	SASS	MH	20	VCI	3	1984	269	0.084
NICKEL	MG/H	50572	MG/H	433	748	SASS	MH	20	VCI	3	1984	269	0.084
PHOSPHORUS	MG/H	15736500	MG/H	597	748	SASS	MH	20	VCI	3	1984	269	0.084
SELENIUM	MG/H	ND	MG/H	26	748	SASS	MH	20	VCI	3	1984	269	0.084
SILVER	MG/H	4761	MG/H	26	748	SASS	MH	20	VCI	3	1984	269	0.084

TABLE R8. COMPILED DATA FOR REFERENCE 8

REF=R8

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SODIUM	MG/H	629460	MG/H	1999	748	SASS	MH	20	VCI	3	1984	269	0.084
SULFUR	MG/H	6402200	MG/H	29904	748	SASS	MH	20	VCI	3	1984	269	0.084
TIN	MG/H	76396	MG/H	391	748	SASS	MH	20	VCI	3	1984	269	0.084
TITANIUM	MG/H	1866860	MG/H	46	748	SASS	MH	20	VCI	3	1984	269	0.084
VANADIUM	MG/H	126699	MG/H	368	748	SASS	MH	20	VCI	3	1984	269	0.084
ZINC	MG/H	1778090	MG/H	1000	748	SASS	MH	20	VCI	3	1984	269	0.084

9. Adams, R.C., G. Bockol, J.A. Maddox, and E.V. Robb, Radian Corporation, "Particulate Removal Evaluation of an Electrostatic Precipitator Dust Removal System Installed on a Multiple Hearth Incinerator Burning Sewage Sludge," Draft, U.S. EPA Water Engineering Research Laboratory, September 30, 1985, EPA Contract No. 68-03-3148.

The object of the study is a multiple hearth (6 hearths) incinerator with two cyclones, a Venturi, and an impingement scrubber in series. As in Reference #8, the study compared the ordinary configuration with a pilot-scale alternative--in this case an electrostatic precipitator. Since the precipitator data are not representative of full scale unit, they are not included. The data from this report may be considered addenda to Reference #8.

The feed rates were obtained from Table 2-1 (p. 2.2). The particulate emission rates were obtained from Table 2-8 (p. 2-15). The metal feed rates were calculated from metal concentrations presented in Table 2-2 (p. 2-4). The metal emission rates were calculated using particulate metal concentrations obtained from tables for runs 1, 2, and 3 (pp. C-2 to C-4).

The Source Assessment Sanpling System (SASS) protocol was used for particulate measurement.

TABLE R9. COMPILED DATA FOR REFERENCE 9

-- REF=R9 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	98.4			726	SASS	MH	20	VCI	1	1985		
ALUMINUM	MG/H	7946400	MG/H	39420	726	SASS	MH	20	VCI	1	1985	264	0.054
ANTIMONY	MG/H	39600	MG/H	37	726	SASS	MH	20	VCI	1	1985	264	0.054
ARSENIC	MG/H	185856	MG/H	198	726	SASS	MH	20	VCI	1	1985	264	0.054
BARIUM	MG/H	691680	MG/H	1193	726	SASS	MH	20	VCI	1	1985	264	0.054
CADMIUM	MG/H	76032	MG/H	1658	726	SASS	MH	20	VCI	1	1985	264	0.054
CALCIUM	MG/H	13728000	MG/H	39096	726	SASS	MH	20	VCI	1	1985	264	0.054
CHROMIUM	MG/H	195624	MG/H	1280	726	SASS	MH	20	VCI	1	1985	264	0.054
COBALT	MG/H	16500	MG/H	10	726	SASS	MH	20	VCI	1	1985	264	0.054
COPPER	MG/H	1386000	MG/H	2284	726	SASS	MH	20	VCI	1	1985	264	0.054
GOLD	MG/H	ND	MG/H	ND	726	SASS	MH	20	VCI	1	1985	264	0.054
IRON	MG/H	14572800	MG/H	11880	726	SASS	MH	20	VCI	1	1985	264	0.054
LEAD	MG/H	248160	MG/H	691	726	SASS	MH	20	VCI	1	1985	264	0.054
MAGNESIUM	MG/H	5887200	MG/H	1296	726	SASS	MH	20	VCI	1	1985	264	0.054
MANGANESE	MG/H	105864	MG/H	180	726	SASS	MH	20	VCI	1	1985	264	0.054
NICKEL	MG/H	86328	MG/H	65	726	SASS	MH	20	VCI	1	1985	264	0.054
PHOSPHORUS	MG/H	14599200	MG/H	3391	726	SASS	MH	20	VCI	1	1985	264	0.054
SELENIUM	MG/H	ND	MG/H	3	726	SASS	MH	20	VCI	1	1985	264	0.054
SILVER	MG/H	ND	MG/H	17	726	SASS	MH	20	VCI	1	1985	264	0.054
SODIUM	MG/H	1998480	MG/H	4779	726	SASS	MH	20	VCI	1	1985	264	0.054
SULFUR	MG/H	4910400	MG/H	52272	726	SASS	MH	20	VCI	1	1985	264	0.054
TIN	MG/H	123288	MG/H	2678	726	SASS	MH	20	VCI	1	1985	264	0.054
TITANIUM	MG/H	1879680	MG/H	2236	726	SASS	MH	20	VCI	1	1985	264	0.054
VANADIUM	MG/H	51480	MG/H	44	726	SASS	MH	20	VCI	1	1985	264	0.054
ZINC	MG/H	1734480	MG/H	3731	726	SASS	MH	20	VCI	1	1985	264	0.054
SCRUBBER	%	98.5			747	SASS	MH	20	VCI	2	1985		
ALUMINUM	MG/H	9549900	MG/H	29677	747	SASS	MH	20	VCI	2	1985	243	0.059
ANTIMONY	MG/H	32805	MG/H	36	747	SASS	MH	20	VCI	2	1985	243	0.059
ARSENIC	MG/H	166455	MG/H	137	747	SASS	MH	20	VCI	2	1985	243	0.059
BARIUM	MG/H	566190	MG/H	979	747	SASS	MH	20	VCI	2	1985	243	0.059
CADMIUM	MG/H	52002	MG/H	2696	747	SASS	MH	20	VCI	2	1985	243	0.059
CALCIUM	MG/H	16013700	MG/H	40238	747	SASS	MH	20	VCI	2	1985	243	0.059
CHROMIUM	MG/H	176904	MG/H	6018	747	SASS	MH	20	VCI	2	1985	243	0.059
COBALT	MG/H	13462	MG/H	33	747	SASS	MH	20	VCI	2	1985	243	0.059
COPPER	MG/H	1232010	MG/H	4183	747	SASS	MH	20	VCI	2	1985	243	0.059

TABLE R9. COMPILED DATA FOR REFERENCE 9

-- REF=R9 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
GOLD	MG/H	238	MG/H	1	747	SASS	MH	20	VCI	2	1985	243	0.059
IRON	MG/H	14239800	MG/H	38704	747	SASS	MH	20	VCI	2	1985	243	0.059
LEAD	MG/H	247860	MG/H	4714	747	SASS	MH	20	VCI	2	1985	243	0.059
MAGNESIUM	MG/H	5977800	MG/H	1634	747	SASS	MH	20	VCI	2	1985	243	0.059
MANGANESE	MG/H	106677	MG/H	690	747	SASS	MH	20	VCI	2	1985	243	0.059
NICKEL	MG/H	59292	MG/H	2820	747	SASS	MH	20	VCI	2	1985	243	0.059
PHOSPHORUS	MG/H	13170600	MG/H	820	747	SASS	MH	20	VCI	2	1985	243	0.059
SELENIUM	MG/H	ND	MG/H	3770	747	SASS	MH	20	VCI	2	1985	243	0.059
SILVER	MG/H	ND	MG/H	15	747	SASS	MH	20	VCI	2	1985	243	0.059
SODIUM	MG/H	1866240	MG/H	7965	747	SASS	MH	20	VCI	2	1985	243	0.059
SULFUR	MG/H	5005800	MG/H	79060	747	SASS	MH	20	VCI	2	1985	243	0.059
TIN	MG/H	101574	MG/H	3375	747	SASS	MH	20	VCI	2	1985	243	0.059
TITANIUM	MG/H	1562490	MG/H	814	747	SASS	MH	20	VCI	2	1985	243	0.059
VANADIUM	MG/H	50058	MG/H	267	747	SASS	MH	20	VCI	2	1985	243	0.059
ZINC	MG/H	1807920	MG/H	5304	747	SASS	MH	20	VCI	2	1985	243	0.059
SCRUBBER	%	97.6			774	SASS	MH	20	VCI	3	1985		
ALUMINUM	MG/H	11954800	MG/H	167240	774	SASS	MH	20	VCI	3	1985	242	0.113
ANTIMONY	MG/H	18174	MG/H	79	774	SASS	MH	20	VCI	3	1985	242	0.113
ARSENIC	MG/H	193116	MG/H	314	774	SASS	MH	20	VCI	3	1985	242	0.113
BARIUM	MG/H	573540	MG/H	2735	774	SASS	MH	20	VCI	3	1985	242	0.113
CADMIUM	MG/H	47190	MG/H	1356	774	SASS	MH	20	VCI	3	1985	242	0.113
CALCIUM	MG/H	19093800	MG/H	273460	774	SASS	MH	20	VCI	3	1985	242	0.113
CHROMIUM	MG/H	208362	MG/H	7	774	SASS	MH	20	VCI	3	1985	242	0.113
COBALT	MG/H	13237	MG/H	2	774	SASS	MH	20	VCI	3	1985	242	0.113
COPPER	MG/H	1372140	MG/H	1480	774	SASS	MH	20	VCI	3	1985	242	0.113
GOLD	MG/H	ND	MG/H	ND	774	SASS	MH	20	VCI	3	1985	242	0.113
IRON	MG/H	16214000	MG/H	1695	774	SASS	MH	20	VCI	3	1985	242	0.113
LEAD	MG/H	244420	MG/H	2079	774	SASS	MH	20	VCI	3	1985	242	0.113
MAGNESIUM	MG/H	5808000	MG/H	1526	774	SASS	MH	20	VCI	3	1985	242	0.113
MANGANESE	MG/H	118580	MG/H	0.0007	774	SASS	MH	20	VCI	3	1985	242	0.113
NICKEL	MG/H	471900	MG/H	4	774	SASS	MH	20	VCI	3	1985	242	0.113
PHOSPHORUS	MG/H	12438800	MG/H	3017	774	SASS	MH	20	VCI	3	1985	242	0.113
SELENIUM	MG/H	ND	MG/H	13	774	SASS	MH	20	VCI	3	1985	242	0.113
SILVER	MG/H	ND	MG/H	38	774	SASS	MH	20	VCI	3	1985	242	0.113

TABLE R9. COMPILED DATA FOR REFERENCE 9

-- REF=R9 --
(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SODIUM	MG/H	2008600	MG/H	82	774	SASS	MH	20	VCI	3	1985	242	0.113
SULFUR	MG/H	4694800	MG/H	16046	774	SASS	MH	20	VCI	3	1985	242	0.113
TIN	MG/H	106238	MG/H	681	774	SASS	MH	20	VCI	3	1985	242	0.113
TITANIUM	MG/H	1853720	MG/H	405	774	SASS	MH	20	VCI	3	1985	242	0.113
VANADIUM	MG/H	56870	MG/H	47	774	SASS	MH	20	VCI	3	1985	242	0.113
ZINC	MG/H	1848880	MG/H	1153	774	SASS	MH	20	VCI	3	1985	242	0.113

10. Klinger, W.A., TRC Environmental Consultants, "Biological Sludge Incinerator Air Impacts Study," Arlington County Department of Public Works, March 28, 1986.

The facility is a multiple hearth incinerator with a wet scrubber. The Modified Method 5 protocol was used to sample the emissions. The facility was tested in incineration and pyrolysis modes.

Feed and particulate emission rates for the incineration mode were obtained from Table 2-4 (p. 9). Metal emission rates were obtained from Table 2-5 (p. 10).

Feed and particulate emission rates for the pyrolysis mode were obtained from Table 2-7 (p. 13). Metal emission rates were obtained from Table 2-8 (p. 14).

The metal concentrations in the feed were obtained from Table 2-1 (p. 4). Mercury levels in the feed are too low. Either the concentration in the feed is higher or there is another source of mercury.

TABLE R10. COMPILED DATA FOR REFERENCE 10

REF=R10

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
CADMIUM	MG/H	6468	MG/H	2052		M5	MH	21		1	1985	1320	0.925
LEAD	MG/H	127380	MG/H	11088		M5	MH	21		1	1985	1320	0.925
MERCURY	MG/H	620	MG/H	270		M5	MH	21		1	1985	1320	0.925
CADMIUM	MG/H	5772	MG/H	3780		M5	MH	21		2	1985	1178	0.594
LEAD	MG/H	113677	MG/H	61920		M5	MH	21		2	1985	1178	0.594
MERCURY	MG/H	554	MG/H	2808		M5	MH	21		2	1985	1178	0.594
CADMIUM	MG/H	6257	MG/H	3780		M5	MH	21		3	1985	1277	0.612
LEAD	MG/H	123231	MG/H	35676		M5	MH	21		3	1985	1277	0.612
MERCURY	MG/H	600	MG/H	4284		M5	MH	21		3	1985	1277	0.612
CADMIUM	MG/H	5772	MG/H	3888		M5	MH	21		4	1985	1178	0.934
LEAD	MG/H	113677	MG/H	81360		M5	MH	21		4	1985	1178	0.934
MERCURY	MG/H	554	MG/H	2988		M5	MH	21		4	1985	1178	0.934
CADMIUM	MG/H	5777	MG/H	1476		M5	MH	21		5	1985	1179	0.576
LEAD	MG/H	113774	MG/H	14112		M5	MH	21		5	1985	1179	0.576
MERCURY	MG/H	554	MG/H	1224		M5	MH	21		5	1985	1179	0.576
CADMIUM	MG/H	5282	MG/H	2376		M5	MH	21		6	1985	1078	0.753
LEAD	MG/H	104027	MG/H	18576		M5	MH	21		6	1985	1078	0.753
MERCURY	MG/H	507	MG/H	1692		M5	MH	21		6	1985	1078	0.753
CADMIUM	MG/H	5219	MG/H	1548		M5	MH	21		7	1985	1065	0.603
LEAD	MG/H	102773	MG/H	34884		M5	MH	21		7	1985	1065	0.603
MERCURY	MG/H	501	MG/H	2160		M5	MH	21		7	1985	1065	0.603

11. Farrell, J.B. and H. Wall, Ultimate Disposal Section, Municipal Environmental Research Laboratory, "Air Pollution Discharges from Ten Sewage Sludge Incinerators." Revision No. 1: Draft Review Copy, February 5, 1981.

Some of the data reported in this document were presented in Reference #2.

The sludge feed rates, emission rates, and scrubber efficiencies were obtained from Table A-1 (document not paginated).

The metal feed rates were calculated from metal feed concentrations obtained from Table A-4. The metal emission rates were calculated from metal emission concentration rates obtained from Table 9.

A memo from J. Farrell to Elliot Lomnitz suggests that the following incinerators should be omitted from analysis:

Incinerator	Reason to be Omitted
B	Metal emission samples destroyed before analysis
G	No metal emission rates reported
H	Faulty analytical results
J	Facility may not have reached steady state
K	Wet cyclone inadequate to control emissions.

TABLE R11. COMPILED DATA FOR REFERENCE 11

-- REF=R11 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	98.2				SASS	MH	2	I	1	1979		
SILVER	MG/H	28182	MG/H	424		SASS	MH	2	I	1	1979	1281	0.918
CADMIUM	MG/H	43554	MG/H	5556		SASS	MH	2	I	1	1979	1281	0.918
CHROMIUM	MG/H	1813896	MG/H	2080		SASS	MH	2	I	1	1979	1281	0.918
COPPER	MG/H	2578653	MG/H	7392		SASS	MH	2	I	1	1979	1281	0.918
IRON	MG/H	16131633	MG/H	14913		SASS	MH	2	I	1	1979	1281	0.918
MANGANESE	MG/H	666120	MG/H	453		SASS	MH	2	I	1	1979	1281	0.918
NICKEL	MG/H	1015833	MG/H	1769		SASS	MH	2	I	1	1979	1281	0.918
LEAD	MG/H	2408280	MG/H	41420		SASS	MH	2	I	1	1979	1281	0.918
ZINC	MG/H	2946300	MG/H	9290		SASS	MH	2	I	1	1979	1281	0.918
SCRUBBER	%	92.0				SASS	MH	22	I	1	1979		
SILVER	MG/H	26543	MG/H			SASS	MH	22	I	1	1979	1397	0.561
CADMIUM	MG/H	417703	MG/H			SASS	MH	22	I	1	1979	1397	0.561
CHROMIUM	MG/H	2105279	MG/H			SASS	MH	22	I	1	1979	1397	0.561
COPPER	MG/H	588137	MG/H			SASS	MH	22	I	1	1979	1397	0.561
IRON	MG/H	80560799	MG/H			SASS	MH	22	I	1	1979	1397	0.561
MANGANESE	MG/H	465201	MG/H			SASS	MH	22	I	1	1979	1397	0.561
NICKEL	MG/H	146685	MG/H			SASS	MH	22	I	1	1979	1397	0.561
LEAD	MG/H	782320	MG/H			SASS	MH	22	I	1	1979	1397	0.561
ZINC	MG/H	5159121	MG/H			SASS	MH	22	I	1	1979	1397	0.561
SCRUBBER	%	99.9				SASS	MH	23	VI	1	1979		
SILVER	MG/H	1860	MG/H			SASS	MH	23	VI	1	1979	93	0.050
CADMIUM	MG/H		MG/H			SASS	MH	23	VI	1	1979	93	0.050
CHROMIUM	MG/H	103044	MG/H			SASS	MH	23	VI	1	1979	93	0.050
COPPER	MG/H	248031	MG/H			SASS	MH	23	VI	1	1979	93	0.050
IRON	MG/H	573717	MG/H			SASS	MH	23	VI	1	1979	93	0.050
MANGANESE	MG/H	48732	MG/H			SASS	MH	23	VI	1	1979	93	0.050
NICKEL	MG/H	14694	MG/H			SASS	MH	23	VI	1	1979	93	0.050
LEAD	MG/H	34875	MG/H			SASS	MH	23	VI	1	1979	93	0.050
ZINC	MG/H	246729	MG/H			SASS	MH	23	VI	1	1979	93	0.050
SCRUBBER	%	92.3				SASS	MH	3	I	1	1979		
SILVER	MG/H	105522	MG/H	739		SASS	MH	3	I	1	1979	2441	1.63
CADMIUM	MG/H	346622	MG/H	62494		SASS	MH	3	I	1	1979	2441	1.63
CHROMIUM	MG/H	2228633	MG/H	4762		SASS	MH	3	I	1	1979	2441	1.63
COPPER	MG/H	2489820	MG/H	7980		SASS	MH	3	I	1	1979	2441	1.63

TABLE R11. COMPILED DATA FOR REFERENCE 11

-- REF=R11 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
IRON	MG/H	168673100	MG/H	23653		SASS	MH	3	I	1	1979	2441	1.63
MANGANESE	MG/H	1384047	MG/H	453		SASS	MH	3	I	1	1979	2441	1.63
NICKEL	MG/H	3449133	MG/H	2349		SASS	MH	3	I	1	1979	2441	1.63
LEAD	MG/H	1789253	MG/H	32259		SASS	MH	3	I	1	1979	2441	1.63
ZINC	MG/H	9781087	MG/H	79030		SASS	MH	3	I	1	1979	2441	1.63
SCRUBBER	%	99.2				SASS	MH	4	I	1	1979		
SILVER	MG/H	63342	MG/H	1184		SASS	MH	4	I	1	1979	1173	2.03
CADMIUM	MG/H	8211	MG/H	2046		SASS	MH	4	I	1	1979	1173	2.03
CHROMIUM	MG/H	480930	MG/H	2663		SASS	MH	4	I	1	1979	1173	2.03
COPPER	MG/H	876231	MG/H	11525		SASS	MH	4	I	1	1979	1173	2.03
IRON	MG/H	22623651	MG/H	16053		SASS	MH	4	I	1	1979	1173	2.03
MANGANESE	MG/H	353073	MG/H	3300		SASS	MH	4	I	1	1979	1173	2.03
NICKEL	MG/H	330786	MG/H	1889		SASS	MH	4	I	1	1979	1173	2.03
LEAD	MG/H	289731	MG/H	55155		SASS	MH	4	I	1	1979	1173	2.03
ZINC	MG/H	679167	MG/H	44664		SASS	MH	4	I	1	1979	1173	2.03
SCRUBBER	%	94.7				SASS	MH	5	VI	1	1979		
SILVER	MG/H	36708	MG/H	90		SASS	MH	5	VI	1	1979	1596	0.205
CADMIUM	MG/H	17556	MG/H	654		SASS	MH	5	VI	1	1979	1596	0.205
CHROMIUM	MG/H	734160	MG/H	170		SASS	MH	5	VI	1	1979	1596	0.205
COPPER	MG/H	2296644	MG/H	737		SASS	MH	5	VI	1	1979	1596	0.205
IRON	MG/H	145395600	MG/H	1681		SASS	MH	5	VI	1	1979	1596	0.205
MANGANESE	MG/H	2014152	MG/H	49		SASS	MH	5	VI	1	1979	1596	0.205
NICKEL	MG/H	1372560	MG/H	115		SASS	MH	5	VI	1	1979	1596	0.205
LEAD	MG/H	1197000	MG/H	30750		SASS	MH	5	VI	1	1979	1596	0.205
ZINC	MG/H	7043148	MG/H	13570		SASS	MH	5	VI	1	1979	1596	0.205
SCRUBBER	%	89.5				SASS	MH	6	VI	1	1979		
SILVER	MG/H	18720	MG/H	272		SASS	MH	6	VI	1	1979	936	0.555
CADMIUM	MG/H	6552	MG/H	210		SASS	MH	6	VI	1	1979	936	0.555
CHROMIUM	MG/H	171288	MG/H	406		SASS	MH	6	VI	1	1979	936	0.555
COPPER	MG/H	277992	MG/H	973		SASS	MH	6	VI	1	1979	936	0.555
IRON	MG/H	47049912	MG/H	10043		SASS	MH	6	VI	1	1979	936	0.555
MANGANESE	MG/H	322920	MG/H	96		SASS	MH	6	VI	1	1979	936	0.555
NICKEL	MG/H	113256	MG/H	83		SASS	MH	6	VI	1	1979	936	0.555
LEAD	MG/H	199368	MG/H	5793		SASS	MH	6	VI	1	1979	936	0.555

TABLE R11. COMPILED DATA FOR REFERENCE 11

REF=R11

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ZINC	MG/H	811512	MG/H	2647		SASS	MH	6	VI	1	1979	936	0.555
SCRUBBER	%	99.6				SASS	FB	8	VI	1	1979		
SILVER	MG/H	103180	MG/H	7.5		SASS	FB	8	VI	1	1979	1340	0.049
CADMIUM	MG/H	14740	MG/H	2.5		SASS	FB	8	VI	1	1979	1340	0.049
CHROMIUM	MG/H	113900	MG/H	24		SASS	FB	8	VI	1	1979	1340	0.049
COPPER	MG/H	950060	MG/H	19		SASS	FB	8	VI	1	1979	1340	0.049
IRON	MG/H	13239200	MG/H	731		SASS	FB	8	VI	1	1979	1340	0.049
MANGANESE	MG/H	1440500	MG/H	14		SASS	FB	8	VI	1	1979	1340	0.049
NICKEL	MG/H	143380	MG/H	42		SASS	FB	8	VI	1	1979	1340	0.049
LEAD	MG/H	493120	MG/H	353		SASS	FB	8	VI	1	1979	1340	0.049
ZINC	MG/H	1120240	MG/H	78		SASS	MH	8	VI	1	1979	1340	0.049
SCRUBBER	%	85.1				SASS	MH	9	C	1	1979		
SILVER	MG/H	949	MG/H	271		SASS	MH	9	C	1	1979	73	2.45
CADMIUM	MG/H	949	MG/H	567		SASS	MH	9	C	1	1979	73	2.45
CHROMIUM	MG/H	18615	MG/H	2062		SASS	MH	9	C	1	1979	73	2.45
COPPER	MG/H	54531	MG/H	4209		SASS	MH	9	C	1	1979	73	2.45
IRON	MG/H	675688	MG/H	11339		SASS	MH	9	C	1	1979	73	2.45
MANGANESE	MG/H	46063	MG/H	278		SASS	MH	9	C	1	1979	73	2.45
NICKEL	MG/H	9490	MG/H	618		SASS	MH	9	C	1	1979	73	2.45
LEAD	MG/H	63291	MG/H	41633		SASS	MH	9	C	1	1979	73	2.45
ZINC	MG/H	206371	MG/H	25627		SASS	MH	9	C	1	1979	73	2.45

12. U.S. EPA, Emission Measurement Branch, *Emission Test Report Method Development and Testing for Chromium Sewage Sludge Incinerator No. 13*. Detroit Water and Sewer Department, Detroit, Michigan, August 1986, EPA Contract No. 68-02-3849.

The object of this study is a multiple hearth (12) incinerator with an impingement scrubber. Metals other than chromium were detected in the feed and at the inlet to the scrubber. The emissions from the scrubber were not tested for these other metals.

The dry sludge feed rate was determined from calculations based on the wet sludge feed rate averaged over the test intervals (Tables 5-3 through 5-7, pp. 5-6 to 5-10) and total solids data (Table 2-8, p. 2-20).

The particulate emissions data were obtained from Table 2-4 (p. 2-7). The scrubber efficiencies are presented on a mass reduction basis (i.e., mass removed over inlet mass) to maintain consistency with data reported from other studies.

The chromium emissions were obtained from Table 2-9 (p. 2-22). The chromium feed rate was calculated from concentrations reported in Table 2-11 (p. 2-24). It assumed that these concentrations are given on a total or wet basis. The raw data sheet (p. C-70) bears out this assumption.

TABLE R12. COMPILED DATA FOR REFERENCE 12

REF=R12

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	98.5			785	M5	MH	24	I	1	1985		
CHROMIUM	MG/H	2039824	MG/H	2.0	785	M5	MH	24	I	1	1985	2435	1.4
SCRUBBER	%	98.2			777	M5	MH	24	I	2	1985		
CHROMIUM	MG/H	2379987	MG/H	2.0	777	M5	MH	24	I	2	1985	2372	1.6
SCRUBBER	%	98.8			744	M5	MH	24	I	3	1985		
CHROMIUM	MG/H	2409924	MG/H	3.0	744	M5	MH	24	I	3	1985	2761	1.1
SCRUBBER	%	99.0			761	M5	MH	24	I	4	1985		
CHROMIUM	MG/H	1867521	MG/H	2.0	761	M5	MH	24	I	4	1985	3139	1.0

13. Knisley, D.R., L.M. Lamb, and A.M. Smith, Radian Corporation, "Site 1 Draft Emission Test Report. Sewage Sludge Test Program," Draft, July 17, 1987. EPA Water Engineering Research Laboratory. EPA Contract No. 68-02-6999.

The incinerator tested is a multiple hearth (6) incinerator with an impingement (3-tray) scrubber. The unit tested is one of four incinerators operating at the site. Particulates were collected for metals analysis using long-term and short-term versions of EPA Method 12. Semi-volatile organic, PCB, and pesticide emissions were determined using the modified Method 5 (MM5) sampling train. Volatile emissions were obtained using the volatile organic sampling train (VOST). Hexavalent and trivalent chromium emissions were measured at the facility but are not included in the data base due to sampling difficulties.

Short-term metal feed rates were obtained from Table 4-7 (p. 4-11). Short term metal emission rates were obtained from Table 4-3 (p. 4-6). Long-term metal feed rates were obtained from Table 4-18 (p. 4-25). Long-term metal emission rates were obtained from Table 4-14 (p. 4-20). No flue gas samples were obtained at the influent to the scrubber so scrubber efficiencies were not reported. Volatile organic feed rates were determined using concentration data from Table 4-31 (p. 4-43) and sludge feed rates from Table 4-34 (p. 4-47). Volatile organic emissions were obtained from Table 4-28 (p. 4-39). Semi-volatile organic, PCB, and pesticide emissions were obtained from Table 4-39 (p. 4-53). None of these compounds were present at detectable levels in the sludge as reported on page 4-60.

TABLE R13. COMPILED DATA FOR REFERENCE 13

-- REF=R13 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	ND	MG/H	76	829	M12S	MH	25	I	1	1987	734	5.83
BERYLLIUM	MG/H	ND	MG/H	ND	829	M12S	MH	25	I	1	1987	734	5.83
CADMIUM	MG/H	1200	MG/H	510	829	M12S	MH	25	I	1	1987	734	5.83
CHROMIUM	MG/H	131000	MG/H	739	829	M12S	MH	25	I	1	1987	734	5.83
LEAD	MG/H	67800	MG/H	20400	829	M12S	MH	25	I	1	1987	734	5.83
NICKEL	MG/H	14800	MG/H	280	829	M12S	MH	25	I	1	1987	734	5.83
ARSENIC	MG/H	ND	MG/H	54	829	M12S	MH	25	I	2	1987	653	4.80
BERYLLIUM	MG/H	ND	MG/H	ND	829	M12S	MH	25	I	2	1987	653	4.80
CADMIUM	MG/H	1900	MG/H	383	829	M12S	MH	25	I	2	1987	653	4.80
CHROMIUM	MG/H	141000	MG/H	204	829	M12S	MH	25	I	2	1987	653	4.80
LEAD	MG/H	76900	MG/H	17900	829	M12S	MH	25	I	2	1987	653	4.80
NICKEL	MG/H	15800	MG/H	204	829	M12S	MH	25	I	2	1987	653	4.80
ARSENIC	MG/H	ND	MG/H	49	823	M12S	MH	25	I	3	1987	764	4.47
BERYLLIUM	MG/H	600	MG/H	ND	823	M12S	MH	25	I	3	1987	764	4.47
CADMIUM	MG/H	ND	MG/H	376	823	M12S	MH	25	I	3	1987	764	4.47
CHROMIUM	MG/H	161000	MG/H	1880	823	M12S	MH	25	I	3	1987	764	4.47
LEAD	MG/H	67100	MG/H	16100	823	M12S	MH	25	I	3	1987	764	4.47
NICKEL	MG/H	14800	MG/H	9900	823	M12S	MH	25	I	3	1987	764	4.47
ARSENIC	MG/H	ND	MG/H	41	826	M12S	MH	25	I	4	1987	517	2.99
BERYLLIUM	MG/H	500	MG/H	ND	826	M12S	MH	25	I	4	1987	517	2.99
CADMIUM	MG/H	ND	MG/H	290	826	M12S	MH	25	I	4	1987	517	2.99
CHROMIUM	MG/H	123000	MG/H	218	826	M12S	MH	25	I	4	1987	517	2.99
LEAD	MG/H	51800	MG/H	12100	826	M12S	MH	25	I	4	1987	517	2.99
NICKEL	MG/H	8800	MG/H	290	826	M12S	MH	25	I	4	1987	517	2.99
ARSENIC	MG/H	ND	MG/H	101	823	M12L	MH	25	I	5	1987	695	3.37
BERYLLIUM	MG/H	ND	MG/H	ND	823	M12L	MH	25	I	5	1987	695	3.37
CADMIUM	MG/H	ND	MG/H	552	823	M12L	MH	25	I	5	1987	695	3.37
CHROMIUM	MG/H	137000	MG/H	444	823	M12L	MH	25	I	5	1987	695	3.37
LEAD	MG/H	71100	MG/H	22300	823	M12L	MH	25	I	5	1987	695	3.37
NICKEL	MG/H	14900	MG/H	111	823	M12L	MH	25	I	5	1987	695	3.37
ARSENIC	MG/H	ND	MG/H	111	826	M12L	MH	25	I	6	1987	884	4.64
BERYLLIUM	MG/H	ND	MG/H	ND	826	M12L	MH	25	I	6	1987	884	4.64
CADMIUM	MG/H	2200	MG/H	514	826	M12L	MH	25	I	6	1987	884	4.64
CHROMIUM	MG/H	189000	MG/H	251	826	M12L	MH	25	I	6	1987	884	4.64
LEAD	MG/H	77600	MG/H	33100	826	M12L	MH	25	I	6	1987	884	4.64

TABLE R13. COMPILED DATA FOR REFERENCE 13

-- REF=R13 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
NICKEL	MG/H	15000	MG/H	280	826	M12L	MH	25	I	6	1987	884	4.64
ARSENIC	MG/H	ND	MG/H	99	797	M12L	MH	25	I	7	1987	627	3.66
BERYLLIUM	MG/H	500	MG/H	ND	797	M12L	MH	25	I	7	1987	627	3.66
CADMIUM	MG/H	1800	MG/H	716	797	M12L	MH	25	I	7	1987	627	3.66
CHROMIUM	MG/H	152000	MG/H	256	797	M12L	MH	25	I	7	1987	627	3.66
LEAD	MG/H	67300	MG/H	37300	797	M12L	MH	25	I	7	1987	627	3.66
NICKEL	MG/H	10900	MG/H	ND	797	M12L	MH	25	I	7	1987	627	3.66

14. Knisley, D.R., K.W. Barnett, and D.J. Holder, Radian Corporation, "Site 2 Draft Emission Test Program. Sewage Sludge Test Program," Draft, October 19, 1987. EPA Water Engineering Research Laboratory. EPA Contract No. 68-02-6999.

The facility is a multiple hearth (8) incinerator with a Venturi and an impingement (3-tray) scrubber. Metals data were obtained using two modified versions of method 12: short-term and long-term. Semi-volatile organic, PCB, and pesticide emissions were determined using the modified Method 5 (MM5) sampling train; volatile emissions were obtained using the volatile organic sampling train (VOST). Hexavalent and trivalent chromium results are not included in the data base due to sampling difficulties.

Short-term metal feed rates were obtained from Table 4-5 (p. 4-9). Short-term metal emission rates were obtained from Table 4-11 (p. 4-17). Scrubber efficiencies were obtained from Table 4-14 (p. 4-21). Long-term metal feed and emission rates were obtained from Table 4-22 (p. 4-34). Scrubber efficiencies were obtained from Table 4-25 (p. 4-38). VOC emission rates were obtained from Table 4-42 (p. 4-71). VOC feed rates were determined using concentration data from Table 4-44 (p. 4-73) and sludge feed rates from Table 4-48 (p. 4-78). Semi-volatile organic emission rates were obtained from Table 4-60 (p. 4-92). Semi-volatile organic feed rates were determined using concentration data from Table 4-61 (p. 4-94) and sludge feed rates from Table 4-64 (p. 4-97).

TABLE R14. COMPILED DATA FOR REFERENCE 14

--- REF=R14 ---

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	9900	MG/H	498	903	M12S	MH	26	VI	1	1987	1351	0.48
BERYLLIUM	MG/H	430	MG/H	ND	903	M12S	MH	26	VI	1	1987	1351	0.48
CADMIUM	MG/H	12000	MG/H	1799	903	M12S	MH	26	VI	1	1987	1351	0.48
CHROMIUM	MG/H	105000	MG/H	417	903	M12S	MH	26	VI	1	1987	1351	0.48
LEAD	MG/H	143000	MG/H	4979	903	M12S	MH	26	VI	1	1987	1351	0.48
NICKEL	MG/H	110000	MG/H	671	903	M12S	MH	26	VI	1	1987	1351	0.48
SCRUBBER	%	96.5			903	M12S	MH	26	VI	1	1987	1351	0.48
ARSENIC	MG/H	9300	MG/H	462	889	M12S	MH	26	VI	2	1987	1313	0.51
BERYLLIUM	MG/H	400	MG/H	ND	889	M12S	MH	26	VI	2	1987	1313	0.51
CADMIUM	MG/H	11000	MG/H	1779	889	M12S	MH	26	VI	2	1987	1313	0.51
CHROMIUM	MG/H	112000	MG/H	3086	889	M12S	MH	26	VI	2	1987	1313	0.51
LEAD	MG/H	134000	MG/H	4222	889	M12S	MH	26	VI	2	1987	1313	0.51
NICKEL	MG/H	120000	MG/H	7378	889	M12S	MH	26	VI	2	1987	1313	0.51
SCRUBBER	%	95.5			889	M12S	MH	26	VI	2	1987	1313	0.51
ARSENIC	MG/H	8800	MG/H	446	889	M12S	MH	26	VI	3	1987	1250	0.58
BERYLLIUM	MG/H	430	MG/H	ND	889	M12S	MH	26	VI	3	1987	1250	0.58
CADMIUM	MG/H	11000	MG/H	2435	889	M12S	MH	26	VI	3	1987	1250	0.58
CHROMIUM	MG/H	109000	MG/H	2342	889	M12S	MH	26	VI	3	1987	1250	0.58
LEAD	MG/H	129000	MG/H	3409	889	M12S	MH	26	VI	3	1987	1250	0.58
NICKEL	MG/H	116000	MG/H	6186	889	M12S	MH	26	VI	3	1987	1250	0.58
SCRUBBER	%	95.2			889	M12S	MH	26	VI	3	1987	1250	0.58
ARSENIC	MG/H	7800	MG/H	394	834	M12S	MH	26	VI	4	1987	1324	0.50
BERYLLIUM	MG/H	470	MG/H	ND	834	M12S	MH	26	VI	4	1987	1324	0.50
CADMIUM	MG/H	11000	MG/H	2564	834	M12S	MH	26	VI	4	1987	1324	0.50
CHROMIUM	MG/H	110000	MG/H	747	834	M12S	MH	26	VI	4	1987	1324	0.50
LEAD	MG/H	134000	MG/H	4178	834	M12S	MH	26	VI	4	1987	1324	0.50
NICKEL	MG/H	116000	MG/H	2059	834	M12S	MH	26	VI	4	1987	1324	0.50
SCRUBBER	%	94.8			834	M12S	MH	26	VI	4	1987	1324	0.50
ARSENIC	MG/H	7600	MG/H	940	896	M12L	MH	26	VI	5	1987	1440	0.56
BERYLLIUM	MG/H	420	MG/H	ND	896	M12L	MH	26	VI	5	1987	1440	0.56
CADMIUM	MG/H	13700	MG/H	3200	896	M12L	MH	26	VI	5	1987	1440	0.56
CHROMIUM	MG/H	108000	MG/H	470	896	M12L	MH	26	VI	5	1987	1440	0.56
LEAD	MG/H	142000	MG/H	8900	896	M12L	MH	26	VI	5	1987	1440	0.56
NICKEL	MG/H	107000	MG/H	1800	896	M12L	MH	26	VI	5	1987	1440	0.56
SCRUBBER	%	95.8			896	M12L	MH	26	VI	5	1987	1440	0.56

TABLE R14. COMPILED DATA FOR REFERENCE 14

REF=R14

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	5300	MG/H	180	813	M12L	MH	26	VI	6	1987	1070	0.38
BERYLLIUM	MG/H	440	MG/H	ND	813	M12L	MH	26	VI	6	1987	1070	0.38
CADMIUM	MG/H	9800	MG/H	1900	813	M12L	MH	26	VI	6	1987	1070	0.38
CHROMIUM	MG/H	88100	MG/H	290	813	M12L	MH	26	VI	6	1987	1070	0.38
LEAD	MG/H	95900	MG/H	3000	813	M12L	MH	26	VI	6	1987	1070	0.38
NICKEL	MG/H	100000	MG/H	280	813	M12L	MH	26	VI	6	1987	1070	0.38
SCRUBBER	%	96.0			813	M12L	MH	26	VI	6	1987	1070	0.38
ARSENIC	MG/H	6900	MG/H	470	894	M12L	MH	26	VI	7	1987	1350	0.53
BERYLLIUM	MG/H	640	MG/H	1	894	M12L	MH	26	VI	7	1987	1350	0.53
CADMIUM	MG/H	11300	MG/H	2500	894	M12L	MH	26	VI	7	1987	1350	0.53
CHROMIUM	MG/H	113000	MG/H	1300	894	M12L	MH	26	VI	7	1987	1350	0.53
LEAD	MG/H	125000	MG/H	5800	894	M12L	MH	26	VI	7	1987	1350	0.53
NICKEL	MG/H	116000	MG/H	4200	894	M12L	MH	26	VI	7	1987	1350	0.53
SCRUBBER	%	94.4			894	M12L	MH	26	VI	7	1987	1350	0.53

15. Knisley, D.R., K.W. Barnett, and D.J. Holder, Radian Corporation, "Site 3 Draft Emission Test Program. Sewage Sludge Test Program," Draft, October 1, 1987. EPA Water Engineering Research Laboratory. EPA Contract No. 68-02-6999.

The facility is a fluidized bed incinerator with a Venturi and an impingement (3-tray) scrubber. Metals data were obtained using EPA Method 12. Semi-volatile organic, PCB, and pesticide emissions were determined using the Modified Method 5 (MM5) sampling train. Volatile emissions were determined using the volatile organic sampling train (VOST). Hexavalent and trivalent chromium results were obtained but are not included in the data base due to sampling difficulties.

Metal emission rates were obtained from Table 4-3 (p. 4-5). Metal feed rates were obtained from Table 4-7 (p. 4-10). Particulate emissions were obtained from Table 4-9 (p. 4-13). Scrubber efficiencies were not calculable since no particulate measurements were taken at the influent to the scrubber. VOC emissions were obtained from Table 4-14 (p. 4-20). VOC feed rates were obtained from Table 4-18 (p. 4-25). Semi-volatile organic feed rates were obtained from Table 4-28 (p. 4-38) and Table 4-29 (p. 4-30). Semi-volatile organic emission rates were calculated using concentration data from Table 4-26 (p. 4-35) and the flue gas flow rates from Table 4-25 (p. 4-34).

TABLE R15. COMPILED DATA FOR REFERENCE 15

-- REF=R15 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	23500	MG/H	30.7	766	M12	FB	27	VI	1	1987	830	0.411
BERYLLIUM	MG/H	600	MG/H	ND	766	M12	FB	27	VI	1	1987	830	0.411
CADMIUM	MG/H	5900	MG/H	240	766	M12	FB	27	VI	1	1987	830	0.411
CHROMIUM	MG/H	255000	MG/H	748	766	M12	FB	27	VI	1	1987	830	0.411
LEAD	MG/H	269000	MG/H	467	766	M12	FB	27	VI	1	1987	830	0.411
NICKEL	MG/H	1190000	MG/H	7406	766	M12	FB	27	VI	1	1987	830	0.411
ARSENIC	MG/H	28400	MG/H	26.1	768	M12	FB	27	VI	2	1987	1060	0.444
BERYLLIUM	MG/H	700	MG/H	ND	768	M12	FB	27	VI	2	1987	1060	0.444
CADMIUM	MG/H	7400	MG/H	237	768	M12	FB	27	VI	2	1987	1060	0.444
CHROMIUM	MG/H	316000	MG/H	940	768	M12	FB	27	VI	2	1987	1060	0.444
LEAD	MG/H	368000	MG/H	519	768	M12	FB	27	VI	2	1987	1060	0.444
NICKEL	MG/H	1310000	MG/H	6182	768	M12	FB	27	VI	2	1987	1060	0.444
ARSENIC	MG/H	24300	MG/H	23.7	768	M12	FB	27	VI	3	1987	1130	0.307
BERYLLIUM	MG/H	700	MG/H	ND	768	M12	FB	27	VI	3	1987	1130	0.307
CADMIUM	MG/H	6800	MG/H	339	768	M12	FB	27	VI	3	1987	1130	0.307
CHROMIUM	MG/H	277000	MG/H	475	768	M12	FB	27	VI	3	1987	1130	0.307
LEAD	MG/H	416000	MG/H	363	768	M12	FB	27	VI	3	1987	1130	0.307
NICKEL	MG/H	1130000	MG/H	4239	768	M12	FB	27	VI	3	1987	1130	0.307

16. Knisley, D.R., K.W. Barnett, and D.J. Holder, Radian Corporation, "Site 4 Draft Emission Test Program. Sewage Sludge Test Program," Draft, May, 1988. EPA Water Engineering Research Laboratory. EPA Contract No. 68-02-6999.

The incinerator tested is a multiple hearth (6) incinerator with a Venturi and an impingement (4-tray) scrubber. Metals and particulate data were obtained using EPA Method 12. Semi-volatile organic, PCB, and pesticide emissions were determined using the Modified Method 5 (MM5) sampling train at the influent to the scrubber; since no samples were collected at the scrubber exhaust, the scrubber influent results were incorporated into the data base. Volatile organic emissions were determined using the volatile organic sampling train (VOST). Hexavalent, trivalent, and total chromium emissions were measured at the facility but are not included in the data base due to sampling difficulties. Dioxin and furan emissions were determined using MM5 at the scrubber exhaust.

Metal feed rates were obtained from Table 4-11 (p. 4-15). Metal emission rates were obtained from Table 4-8 (p. 4-12). Scrubber efficiencies were obtained from Table 4-24 (p. 4-32). Volatile organic feed rates were obtained from Table 4-41 (p. 4-67). Volatile organic emissions were obtained from Table 4-39 (p. 4-65). Semi-volatile organic, PCB, and pesticide feed rates were obtained from Table 4-57 (p. 4-88). Semi-volatile organic, PCB, and pesticide emissions were obtained from Table 4-54 (p. 4-84). Dioxin and furan feed rates were obtained from Table 4-66 (p. 4-103). Dioxin and furan emissions were obtained from Table 4-62 (p. 4-96).

TABLE R16. COMPILED DATA FOR REFERENCE 16

-- REF=R16 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	1500	MG/H	ND	676	M12	MH	28	VI	1	1987	574	0.91
BERYLLIUM	MG/H	170	MG/H	ND	676	M12	MH	28	VI	1	1987	574	0.91
CADMIUM	MG/H	4900	MG/H	1029	676	M12	MH	28	VI	1	1987	574	0.91
COPPER	MG/H	425000	MG/H	2063	676	M12	MH	28	VI	1	1987	574	0.91
LEAD	MG/H	138000	MG/H	7847	676	M12	MH	28	VI	1	1987	574	0.91
NICKEL	MG/H	161000	MG/H	345	676	M12	MH	28	VI	1	1987	574	0.91
SELENIUM	MG/H	460	MG/H	ND	676	M12	MH	28	VI	1	1987	574	0.91
ZINC	MG/H	344000	MG/H	15144	676	M12	MH	28	VI	1	1987	574	0.91
ARSENIC	MG/H	1500	MG/H	ND	766	M12	MH	28	VI	10	1987	570	0.55
BERYLLIUM	MG/H	170	MG/H	ND	766	M12	MH	28	VI	10	1987	570	0.55
CADMIUM	MG/H	8500	MG/H	1814	766	M12	MH	28	VI	10	1987	570	0.55
COPPER	MG/H	435000	MG/H	3672	766	M12	MH	28	VI	10	1987	570	0.55
LEAD	MG/H	209000	MG/H	28819	766	M12	MH	28	VI	10	1987	570	0.55
NICKEL	MG/H	164000	MG/H	157	766	M12	MH	28	VI	10	1987	570	0.55
SELENIUM	MG/H	730	MG/H	ND	766	M12	MH	28	VI	10	1987	570	0.55
ZINC	MG/H	350000	MG/H	34888	766	M12	MH	28	VI	10	1987	570	0.55
SCRUBBER	%	97.4			766	M12	MH	28	VI	10	1987	570	0.55
ARSENIC	MG/H	1300	MG/H	ND	932	M12	MH	28	VI	11	1987	575	0.85
BERYLLIUM	MG/H	170	MG/H	ND	932	M12	MH	28	VI	11	1987	575	0.85
CADMIUM	MG/H	8600	MG/H	1541	932	M12	MH	28	VI	11	1987	575	0.85
COPPER	MG/H	479000	MG/H	4512	932	M12	MH	28	VI	11	1987	575	0.85
LEAD	MG/H	205000	MG/H	22336	932	M12	MH	28	VI	11	1987	575	0.85
NICKEL	MG/H	177000	MG/H	249	932	M12	MH	28	VI	11	1987	575	0.85
SELENIUM	MG/H	680	MG/H	ND	932	M12	MH	28	VI	11	1987	575	0.85
ZINC	MG/H	371000	MG/H	37310	932	M12	MH	28	VI	11	1987	575	0.85
ARSENIC	MG/H	2100	MG/H	ND	799	M12	MH	28	VI	2	1987	642	0.41
BERYLLIUM	MG/H	190	MG/H	ND	799	M12	MH	28	VI	2	1987	642	0.41
CADMIUM	MG/H	7100	MG/H	1335	799	M12	MH	28	VI	2	1987	642	0.41
COPPER	MG/H	475000	MG/H	2559	799	M12	MH	28	VI	2	1987	642	0.41
LEAD	MG/H	186000	MG/H	13711	799	M12	MH	28	VI	2	1987	642	0.41
NICKEL	MG/H	135000	MG/H	146	799	M12	MH	28	VI	2	1987	642	0.41
SELENIUM	MG/H	580	MG/H	ND	799	M12	MH	28	VI	2	1987	642	0.41
ZINC	MG/H	404000	MG/H	17331	799	M12	MH	28	VI	2	1987	642	0.41
ARSENIC	MG/H	1900	MG/H	ND	718	M12	MH	28	VI	3	1987	694	0.38
BERYLLIUM	MG/H	180	MG/H	ND	718	M12	MH	28	VI	3	1987	694	0.38

TABLE R16. COMPILED DATA FOR REFERENCE 16

---------- REF=R16 ----------

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
CADMIUM	MG/H	6600	MG/H	1005	718	M12	MH	28	VI	3	1987	694	0.38
COPPER	MG/H	429000	MG/H	1790	718	M12	MH	28	VI	3	1987	694	0.38
LEAD	MG/H	163000	MG/H	8951	718	M12	MH	28	VI	3	1987	694	0.38
NICKEL	MG/H	127000	MG/H	183	718	M12	MH	28	VI	3	1987	694	0.38
SELENIUM	MG/H	540	MG/H	ND	718	M12	MH	28	VI	3	1987	694	0.38
ZINC	MG/H	375000	MG/H	11837	718	M12	MH	28	VI	3	1987	694	0.38
ARSENIC	MG/H	2200	MG/H	4	805	M12	MH	28	VI	4	1987	596	0.38
BERYLLIUM	MG/H	210	MG/H	ND	805	M12	MH	28	VI	4	1987	596	0.38
CADMIUM	MG/H	7600	MG/H	1775	805	M12	MH	28	VI	4	1987	596	0.38
COPPER	MG/H	500000	MG/H	5348	805	M12	MH	28	VI	4	1987	596	0.38
LEAD	MG/H	187000	MG/H	35682	805	M12	MH	28	VI	4	1987	596	0.38
NICKEL	MG/H	118000	MG/H	83	805	M12	MH	28	VI	4	1987	596	0.38
SELENIUM	MG/H	760	MG/H	ND	805	M12	MH	28	VI	4	1987	596	0.38
ZINC	MG/H	424000	MG/H	13035	805	M12	MH	28	VI	4	1987	596	0.38
ARSENIC	MG/H	1700	MG/H	ND	815	M12	MH	28	VI	5	1987	541	1.16
BERYLLIUM	MG/H	180	MG/H	ND	815	M12	MH	28	VI	5	1987	541	1.16
CADMIUM	MG/H	7700	MG/H	2018	815	M12	MH	28	VI	5	1987	541	1.16
COPPER	MG/H	501000	MG/H	3045	815	M12	MH	28	VI	5	1987	541	1.16
LEAD	MG/H	101000	MG/H	20449	815	M12	MH	28	VI	5	1987	541	1.16
NICKEL	MG/H	83000	MG/H	132	815	M12	MH	28	VI	5	1987	541	1.16
SELENIUM	MG/H	830	MG/H	ND	815	M12	MH	28	VI	5	1987	541	1.16
ZINC	MG/H	405000	MG/H	31299	815	M12	MH	28	VI	5	1987	541	1.16
ARSENIC	MG/H	1500	MG/H	ND	906	M12	MH	28	VI	6	1987	540	0.63
BERYLLIUM	MG/H	160	MG/H	ND	906	M12	MH	28	VI	6	1987	540	0.63
CADMIUM	MG/H	7600	MG/H	1153	906	M12	MH	28	VI	6	1987	540	0.63
COPPER	MG/H	449000	MG/H	3796	906	M12	MH	28	VI	6	1987	540	0.63
LEAD	MG/H	276000	MG/H	18273	906	M12	MH	28	VI	6	1987	540	0.63
NICKEL	MG/H	227000	MG/H	106	906	M12	MH	28	VI	6	1987	540	0.63
SELENIUM	MG/H	650	MG/H	ND	906	M12	MH	28	VI	6	1987	540	0.63
ZINC	MG/H	357000	MG/H	20721	906	M12	MH	28	VI	6	1987	540	0.63
ARSENIC	MG/H	1400	MG/H	2	901	M12	MH	28	VI	7	1987	530	0.59
BERYLLIUM	MG/H	160	MG/H	ND	901	M12	MH	28	VI	7	1987	530	0.59
CADMIUM	MG/H	8100	MG/H	1696	901	M12	MH	28	VI	7	1987	530	0.59
COPPER	MG/H	476000	MG/H	5962	901	M12	MH	28	VI	7	1987	530	0.59

TABLE R16. COMPILED DATA FOR REFERENCE 16

REF=R16

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
LEAD	MG/H	205000	MG/H	49806	901	M12	MH	28	VI	7	1987	530	0.59
NICKEL	MG/H	238000	MG/H	500	901	M12	MH	28	VI	7	1987	530	0.59
SELENIUM	MG/H	760	MG/H	ND	901	M12	MH	28	VI	7	1987	530	0.59
ZINC	MG/H	378000	MG/H	32633	901	M12	MH	28	VI	7	1987	530	0.59
ARSENIC	MG/H	1300	MG/H	ND	774	M12	MH	28	VI	8	1987	544	0.85
BERYLLIUM	MG/H	160	MG/H	ND	774	M12	MH	28	VI	8	1987	544	0.85
CADMIUM	MG/H	8000	MG/H	1370	774	M12	MH	28	VI	8	1987	544	0.85
COPPER	MG/H	445000	MG/H	2740	774	M12	MH	28	VI	8	1987	544	0.85
LEAD	MG/H	201000	MG/H	15481	774	M12	MH	28	VI	8	1987	544	0.85
NICKEL	MG/H	180000	MG/H	107	774	M12	MH	28	VI	8	1987	544	0.85
SELENIUM	MG/H	740	MG/H	ND	774	M12	MH	28	VI	8	1987	544	0.85
ZINC	MG/H	366000	MG/H	27546	774	M12	MH	28	VI	8	1987	544	0.85
SCRUBBER	%	96.9			774	M12	MH	28	VI	8	1987	544	0.85
ARSENIC	MG/H	1400	MG/H	4	814	M12	MH	28	VI	9	1987	565	0.69
BERYLLIUM	MG/H	160	MG/H	ND	814	M12	MH	28	VI	9	1987	565	0.69
CADMIUM	MG/H	8200	MG/H	1720	814	M12	MH	28	VI	9	1987	565	0.69
COPPER	MG/H	457000	MG/H	4049	814	M12	MH	28	VI	9	1987	565	0.69
LEAD	MG/H	196000	MG/H	20223	814	M12	MH	28	VI	9	1987	565	0.69
NICKEL	MG/H	201000	MG/H	196	814	M12	MH	28	VI	9	1987	565	0.69
SELENIUM	MG/H	760	MG/H	ND	814	M12	MH	28	VI	9	1987	565	0.69
ZINC	MG/H	359000	MG/H	35300	814	M12	MH	28	VI	9	1987	565	0.69
SCRUBBER	%	96.8			814	M12	MH	28	VI	9	1987	565	0.69

4. SUBSETTING THE DATA BASE FOR DESCRIPTIVE STATISTICS

Due to the differences in the format and detail of data provided in the references used to construct the data base, a subset of the data base was created for preliminary statistical analysis. Complete pollutant observations (i.e., feed and emission levels) and the associated sludge flow rates, particulate flow rates, and scrubber efficiencies were retained in the data subset. Data were omitted for the following reasons:

- Duplication of field data. References 2 and 11 present different analyses of the same field data. The data obtained from Reference 2 are not included in the data base subset. Reference 11 contains more detailed data listings and is included in the data base subset subject to editing of data from incinerators B, G, and H for the reasons cited on page 3-36. Reference 11 data for incinerators J and K were not excluded for the reasons given on page 3-36 because data from other reference studies included in the data base were also generated under less than optimal operating or performance conditions.
- Data omissions. An observation was included in the data base subset only if both the pollutant feed and emission rates were reported. A nondetect result is considered a valid observation for the purpose of constructing the data base subset. References 3, 5, 8, and 11 contained observations not included in the subset due to data omissions.
- Peculiarities in the method of data collection. Reference 6 was excluded from the data base subset due to a lack of correspondence between the samples collected for a pollutant concentration analysis and those collected to determine the feed and emission rates.

Although nearly 23% of the observations in the entire data set were excluded from the preliminary analysis, many of these data may be incorporated in future investigations. For example, an observation excluded from the data base subset because the emission rate was omitted could be used in the determination of an average feed rate. The selection of a particular data base subset will be dependent on the application.

Table 6 presents the observations excluded from analysis by reference number, and Table 7 contains the data, listed by reference, retained for production of descriptive statistics.

TABLE 6. OBSERVATIONS OMITTED FROM THE DATA BASE SUBSET

Reference Number	Data Omitted		
	Incinerator	Sample ID	Pollutant
2	All	All	All
3	10	1	Mercury
	10	2	Mercury
	10	3	Mercury
	10	6	Mercury
	12	1	Mercury
	12	1	Arsenic
	12	2	Mercury
	12	2	Arsenic
	12	3	Mercury
	12	3	Arsenic
	12	1	Silver
	12	2	Silver
	12	3	Silver
5	13	1	Selenium
	13	1	Bromine
6	All	All	All
8	20	1	All
11	22	1	All
	23	1	All

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-------------------- REF=1 --------------------

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	71	MG/H	0.43	704	MM5	FB	1	VI	1	1980	182.9	0.031
CADMIUM	MG/H	732	MG/H	0.07	704	MM5	FB	1	VI	1	1980	182.9	0.031
CHROMIUM	MG/H	8488	MG/H	ND	704	MM5	FB	1	VI	1	1980	182.9	0.031
COPPER	MG/H	168296	MG/H	94	704	MM5	FB	1	VI	1	1980	182.9	0.031
NICKEL	MG/H	5488	MG/H	ND	704	MM5	FB	1	VI	1	1980	182.9	0.031
LEAD	MG/H	42094	MG/H	0.13	704	MM5	FB	1	VI	1	1980	182.9	0.031
ZINC	MG/H	120734	MG/H	ND	704	MM5	FB	1	VI	1	1980	182.9	0.031
ARSENIC	MG/H	71	MG/H	0.36	704	SASS	FB	1	VI	2	1980	182.9	0.009
CADMIUM	MG/H	732	MG/H	1.0	704	SASS	FB	1	VI	2	1980	182.9	0.009
CHROMIUM	MG/H	8488	MG/H	7.3	704	SASS	FB	1	VI	2	1980	182.9	0.009
COPPER	MG/H	168296	MG/H	64	704	SASS	FB	1	VI	2	1980	182.9	0.009
NICKEL	MG/H	5488	MG/H	ND	704	SASS	FB	1	VI	2	1980	182.9	0.009
LEAD	MG/H	42074	MG/H	28	704	SASS	FB	1	VI	2	1980	182.9	0.009
ZINC	MG/H	120734	MG/H	ND	704	SASS	FB	1	VI	2	1980	182.9	0.009
ARSENIC	MG/H	49	MG/H	2.2	816	MM5	FB	1	VI	3	1980	212	0.055
CADMIUM	MG/H	849	MG/H	32.5	816	MM5	FB	1	VI	3	1980	212	0.055
CHROMIUM	MG/H	6364	MG/H	ND	816	MM5	FB	1	VI	3	1980	212	0.055
COPPER	MG/H	178188	MG/H	372	816	MM5	FB	1	VI	3	1980	212	0.055
NICKEL	MG/H	4242	MG/H	ND	816	MM5	FB	1	VI	3	1980	212	0.055
LEAD	MG/H	44546	MG/H	249	816	MM5	FB	1	VI	3	1980	212	0.055
ZINC	MG/H	137883	MG/H	ND	816	MM5	FB	1	VI	3	1980	212	0.055
ARSENIC	MG/H	49	MG/H	0.33	816	SASS	FB	1	VI	4	1980	212	0.007
CADMIUM	MG/H	849	MG/H	7.0	816	SASS	FB	1	VI	4	1980	212	0.007
CHROMIUM	MG/H	6364	MG/H	7.0	816	SASS	FB	1	VI	4	1980	212	0.007
COPPER	MG/H	178188	MG/H	139	816	SASS	FB	1	VI	4	1980	212	0.007
NICKEL	MG/H	4242	MG/H	ND	816	SASS	FB	1	VI	4	1980	212	0.007
LEAD	MG/H	44546	MG/H	112	816	SASS	FB	1	VI	4	1980	212	0.007
ZINC	MG/H	137883	MG/H	58	816	SASS	FB	1	VI	4	1980	212	0.007
ARSENIC	MG/H	64	MG/H	7.4	927	MM5	FB	1	VI	5	1980	236	0.076
CADMIUM	MG/H	945	MG/H	169	927	MM5	FB	1	VI	5	1980	236	0.076
CHROMIUM	MG/H	7089	MG/H	ND	927	MM5	FB	1	VI	5	1980	236	0.076
COPPER	MG/H	226855	MG/H	847	927	MM5	FB	1	VI	5	1980	236	0.076
NICKEL	MG/H	4726	MG/H	ND	927	MM5	FB	1	VI	5	1980	236	0.076
LEAD	MG/H	47261	MG/H	3704	927	MM5	FB	1	VI	5	1980	236	0.076
ZINC	MG/H	146510	MG/H	180	927	MM5	FB	1	VI	5	1980	236	0.076

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=1

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	64	MG/H	1.1	927	SASS	FB	1	VI	6	1980	236	0.045
CADMIUM	MG/H	945	MG/H	382	927	SASS	FB	1	VI	6	1980	236	0.045
CHROMIUM	MG/H	7089	MG/H	47	927	SASS	FB	1	VI	6	1980	236	0.045
COPPER	MG/H	226855	MG/H	2450	927	SASS	FB	1	VI	6	1980	236	0.045
NICKEL	MG/H	4726	MG/H	ND	927	SASS	FB	1	VI	6	1980	236	0.045
LEAD	MG/H	47261	MG/H	3633	927	SASS	FB	1	VI	6	1980	236	0.045
ZINC	MG/H	146510	MG/H	495	927	SASS	FB	1	VI	6	1980	236	0.045

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=3

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
LEAD	MG/H	34609	MG/H	126	760	M5	FB	10	VP	1	1974	853	0.140
CHROMIUM	MG/H	14742	MG/H	108	760	M5	FB	10	VP	1	1974	853	0.140
ARSENIC	MG/H	ND	MG/H	ND	760	M5	FB	10	VP	1	1974	853	0.140
CADMIUM	MG/H	4264	MG/H	238	760	M5	FB	10	VP	1	1974	853	0.140
COPPER	MG/H	103012	MG/H	166	760	M5	FB	10	VP	1	1974	853	0.140
SILVER	MG/H	363	MG/H	ND	760	M5	FB	10	VP	1	1974	853	0.140
ZINC	MG/H	986301	MG/H	185	760	M5	FB	10	VP	1	1974	853	0.140
LEAD	MG/H	25311	MG/H	20	760	M5	FB	10	VP	2	1974	623	0.079
CHROMIUM	MG/H	10750	MG/H	4	760	M5	FB	10	VP	2	1974	623	0.079
ARSENIC	MG/H	ND	MG/H	0.005	760	M5	FB	10	VP	2	1974	623	0.079
CADMIUM	MG/H	3130	MG/H	1	760	M5	FB	10	VP	2	1974	623	0.079
COPPER	MG/H	75252	MG/H	10	760	M5	FB	10	VP	2	1974	623	0.079
SILVER	MG/H	272	MG/H	ND	760	M5	FB	10	VP	2	1974	623	0.079
ZINC	MG/H	720448	MG/H	19	760	M5	FB	10	VP	3	1974	544	0.079
LEAD	MG/H	22090	MG/H	8	760	M5	FB	10	VP	3	1974	544	0.079
CHROMIUM	MG/H	9389	MG/H	9	760	M5	FB	10	VP	3	1974	544	0.079
ARSENIC	MG/H	ND	MG/H	ND	760	M5	FB	10	VP	3	1974	544	0.079
CADMIUM	MG/H	2722	MG/H	21	760	M5	FB	10	VP	3	1974	544	0.079
COPPER	MG/H	65726	MG/H	35	760	M5	FB	10	VP	3	1974	544	0.079
SILVER	MG/H	227	MG/H	ND	760	M5	FB	10	VP	3	1974	544	0.079
ZINC	MG/H	629230	MG/H	34	760	M5	FB	10	VP	4	1974	336	0.142
LEAD	MG/H	6350	MG/H	114	760	M5	FB	10	VP	4	1974	336	0.142
CHROMIUM	MG/H	12701	MG/H	31	760	M5	FB	10	VP	4	1974	336	0.142
ARSENIC	MG/H	ND	MG/H	ND	760	M5	FB	10	VP	4	1974	336	0.142
MERCURY	MG/H	ND	MG/H	375	760	M5	FB	10	VP	4	1974	336	0.142
CADMIUM	MG/H	1361	MG/H	41	760	M5	FB	10	VP	4	1974	336	0.142
COPPER	MG/H	64411	MG/H	71	760	M5	FB	10	VP	4	1974	366	0.142
SILVER	MG/H	3175	MG/H	ND	760	M5	FB	10	VP	4	1974	366	0.142
ZINC	MG/H	137440	MG/H	98	760	M5	FB	10	VP	5	1974	481	0.160
LEAD	MG/H	67586	MG/H	594	760	M5	FB	10	VP	5	1974	481	0.160
CHROMIUM	MG/H	18144	MG/H	215	760	M5	FB	10	VP	5	1974	481	0.160
ARSENIC	MG/H	ND	MG/H	0.02	760	M5	FB	10	VP	5	1974	481	0.160
MERCURY	MG/H	ND	MG/H	544	760	M5	FB	10	VP	5	1974	481	0.160
CADMIUM	MG/H	1814	MG/H	15	760	M5	FB	10	VP	5	1974	481	0.160
COPPER	MG/H	92080	MG/H	75									

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=3 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SILVER	MG/H	4717	MG/H	0.008	760	M5	FB	10	VP	5	1974	481	0.160
ZINC	MG/H	197315	MG/H	147	760	M5	FB	10	VP	5	1974	481	0.160
LEAD	MG/H	51256	MG/H	490	760	M5	FB	10	VP	6	1974	366	0.175
CHROMIUM	MG/H	13608	MG/H	30	760	M5	FB	10	VP	6	1974	366	0.175
ARSENIC	MG/H	ND	MG/H	ND	760	M5	FB	10	VP	6	1974	366	0.175
CADMIUM	MG/H	1361	MG/H	32	760	M5	FB	10	VP	6	1974	366	0.175
COPPER	MG/H	69854	MG/H	102	760	M5	FB	10	VP	6	1974	366	0.175
SILVER	MG/H	3629	MG/H	ND	760	M5	FB	10	VP	6	1974	366	0.175
ZINC	MG/H	149687	MG/H	170	760	M5	FB	10	VP	6	1974	366	0.175
LEAD	MG/H	80287	MG/H	649	766	M5	FB	11	VT	1	1974	203	0.076
CHROMIUM	MG/H	33113	MG/H	517	766	M5	FB	11	VT	1	1974	203	0.076
ARSENIC	MG/H	5443	MG/H	ND	766	M5	FB	11	VT	1	1974	203	0.076
MERCURY	MG/H	367	MG/H	74	766	M5	FB	11	VT	1	1974	203	0.076
CADMIUM	MG/H	6804	MG/H	27	766	M5	FB	11	VT	1	1974	203	0.076
COPPER	MG/H	159666	MG/H	18	766	M5	FB	11	VT	1	1974	203	0.076
SILVER	MG/H	2722	MG/H	5	766	M5	FB	11	VT	1	1974	203	0.076
ZINC	MG/H	125646	MG/H	649	766	M5	FB	11	VT	1	1974	203	0.076
LEAD	MG/H	11567	MG/H	308	760	MM5	FB	12	VI	1	1971	231	0.255
CHROMIUM	MG/H	115667	MG/H	151	760	MM5	FB	12	VI	1	1971	231	0.255
CADMIUM	MG/H	134174	MG/H	29	760	MM5	FB	12	VI	1	1971	231	0.255
COPPER	MG/H	393269	MG/H	625	760	MM5	FB	12	VI	1	1971	231	0.255
ZINC	MG/H	323868	MG/H	750	760	MM5	FB	12	VI	1	1971	231	0.255
LEAD	MG/H	10750	MG/H	117	760	MM5	FB	12	VI	2	1971	215	0.348
CHROMIUM	MG/H	107502	MG/H	151	760	MM5	FB	12	VI	2	1971	215	0.348
CADMIUM	MG/H	124694	MG/H	33	760	MM5	FB	12	VI	2	1971	215	0.348
COPPER	MG/H	365508	MG/H	709	760	MM5	FB	12	VI	2	1971	215	0.348
ZINC	MG/H	301007	MG/H	3125	760	MM5	FB	12	VI	2	1971	215	0.348
LEAD	MG/H	9163	MG/H	279	760	MM5	FB	12	VI	3	1971	183	0.260
CHROMIUM	MG/H	91400	MG/H	188	760	MM5	FB	12	VI	3	1971	183	0.260
CADMIUM	MG/H	106006	MG/H	29	760	MM5	FB	12	VI	3	1971	183	0.260
COPPER	MG/H	310759	MG/H	792	760	MM5	FB	12	VI	3	1971	183	0.260
ZINC	MG/H	255919	MG/H	3750	760	MM5	FB	12	VI	3	1971	183	0.260

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=4 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SODIUM	MG/H	440000	MG/H	342	760	MM5	FB	10	VP	1	1981		
CAESIUM	MG/H	306	MG/H	0.050	760	MM5	FB	10	VP	1	1981	600	
MAGNESIUM	MG/H	1500000	MG/H	198	760	MM5	FB	10	VP	1	1981	600	
CALCIUM	MG/H	27600000	MG/H	2700	760	MM5	FB	10	VP	1	1981	600	
BARIUM	MG/H	426000	MG/H	306	760	MM5	FB	10	VP	1	1981	600	
CHLORINE	MG/H	540000	MG/H	90	760	MM5	FB	10	VP	1	1981	600	
BROMINE	MG/H	30000	MG/H	29	760	MM5	FB	10	VP	1	1981	600	
ALUMINUM	MG/H	17400000	MG/H	648	760	MM5	FB	10	VP	1	1981	600	
SCANDIUM	MG/H	1140	MG/H	0.042	760	MM5	FB	10	VP	1	1981	600	
TITANIUM	MG/H	1260000	MG/H	69	760	MM5	FB	10	VP	1	1981	600	
VANADIUM	MG/H	15000	MG/H	3.7	760	MM5	FB	10	VP	1	1981	600	
CHROMIUM	MG/H	78000	MG/H	5.9	760	MM5	FB	10	VP	1	1981	600	
MANGANESE	MG/H	780000	MG/H	15	760	MM5	FB	10	VP	1	1981	600	
IRON	MG/H	24600000	MG/H	1530	760	MM5	FB	10	VP	1	1981	600	
COBALT	MG/H	10200	MG/H	0.75	760	MM5	FB	10	VP	1	1981	600	
COPPER	MG/H	300000	MG/H	35	760	MM5	FB	10	VP	1	1981	600	
ZINC	MG/H	576000	MG/H	64	760	MM5	FB	10	VP	1	1981	600	
SELENIUM	MG/H	1140	MG/H	6.0	760	MM5	FB	10	VP	1	1981	600	
SILVER	MG/H	17400	MG/H	7.2	760	MM5	FB	10	VP	1	1981	600	
CADMIUM	MG/H	7200	MG/H	7.3	760	MM5	FB	10	VP	1	1981	600	
INDIUM	MG/H	ND	MG/H	0.008	760	MM5	FB	10	VP	1	1981	600	
ANTIMONY	MG/H	2640	MG/H	1.2	760	MM5	FB	10	VP	1	1981	600	
CERIUM	MG/H	18000	MG/H	3.5	760	MM5	FB	10	VP	1	1981	600	
EUROPIUM	MG/H	228	MG/H	0.018	760	MM5	FB	10	VP	1	1981	600	
YTTERBIUM	MG/H	360	MG/H	0.360	760	MM5	FB	10	VP	1	1981	600	
TANTALUM	MG/H	258	MG/H	0.003	760	MM5	FB	10	VP	1	1981	600	
LEAD	MG/H	258000	MG/H	82	760	MM5	FB	10	VP	1	1981	600	

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=5 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	99.7			733	M5	MH	13	I	1	1979		
SODIUM	MG/H	19400000	MG/H	24564	733	M5	MH	13	I	1	1979	1940	0.89
MAGNESIUM	MG/H	34920000	MG/H	6319	733	M5	MH	13	I	1	1979	1940	0.89
ALUMINUM	MG/H	65960000	MG/H	9078	733	M5	MH	13	I	1	1979	1940	0.89
SILICON	MG/H	195940000	MG/H	41741	733	M5	MH	13	I	1	1979	1940	0.89
PHOSPHORUS	MG/H	124160000	MG/H	41741	733	M5	MH	13	I	1	1979	1940	0.89
SULFUR	MG/H	18042000	MG/H	46725	733	M5	MH	13	I	1	1979	1940	0.89
CHLORINE	MG/H	8730000	MG/H	16020	733	M5	MH	13	I	1	1979	1940	0.89
POTASSIUM	MG/H	25220000	MG/H	15219	733	M5	MH	13	I	1	1979	1940	0.89
CALCIUM	MG/H	329800000	MG/H	55180	733	M5	MH	13	I	1	1979	1940	0.89
TITANIUM	MG/H	16296000	MG/H	1958	733	M5	MH	13	I	1	1979	1940	0.89
VANADIUM	MG/H	582000	MG/H	2492	733	M5	MH	13	I	1	1979	1940	0.89
CHROMIUM	MG/H	4268000	MG/H	6853	733	M5	MH	13	I	1	1979	1940	0.89
MANGANESE	MG/H	13580000	MG/H	1869	733	M5	MH	13	I	1	1979	1940	0.89
IRON	MG/H	129980000	MG/H	25899	733	M5	MH	13	I	1	1979	1940	0.89
COBALT	MG/H	194000	MG/H	ND	733	M5	MH	13	I	1	1979	1940	0.89
NICKEL	MG/H	582000	MG/H	ND	733	M5	MH	13	I	1	1979	1940	0.89
COPPER	MG/H	2328000	MG/H	ND	733	M5	MH	13	I	1	1979	1940	0.89
ZINC	MG/H	5820000	MG/H	57316	733	M5	MH	13	I	1	1979	1940	0.89
CADMIUM	MG/H	388000	MG/H	2937	733	M5	MH	13	I	1	1979	1940	0.89
TIN	MG/H	5820000	MG/H	12638	733	M5	MH	13	I	1	1979	1940	0.89
ANTIMONY	MG/H	582000	MG/H	445	733	M5	MH	13	I	1	1979	1940	0.89
BARIUM	MG/H	4850000	MG/H	712	733	M5	MH	13	I	1	1979	1940	0.89
LEAD	MG/H	6596000	MG/H	36223	733	M5	MH	13	I	1	1979	1940	0.89
SCRUBBER	%	87.2			643	M5	MH	14	I	1	1979		
SODIUM	MG/H	12180000	MG/H	16986	643	M5	MH	14	I	1	1979	1740	2.98
MAGNESIUM	MG/H	17400000	MG/H	25628	643	M5	MH	14	I	1	1979	1740	2.98
ALUMINUM	MG/H	62640000	MG/H	90890	643	M5	MH	14	I	1	1979	1740	2.98
SILICON	MG/H	226200000	MG/H	242274	643	M5	MH	14	I	1	1979	1740	2.98
PHOSPHORUS	MG/H	76560000	MG/H	100128	643	M5	MH	14	I	1	1979	1740	2.98
SULFUR	MG/H	22620000	MG/H	53640	643	M5	MH	14	I	1	1979	1740	2.98
CHLORINE	MG/H	1392000	MG/H	7748	643	M5	MH	14	I	1	1979	1740	2.98
POTASSIUM	MG/H	19140000	MG/H	26522	643	M5	MH	14	I	1	1979	1740	2.98
CALCIUM	MG/H	107880000	MG/H	151682	643	M5	MH	14	I	1	1979	1740	2.98
TITANIUM	MG/H	13224000	MG/H	26224	643	M5	MH	14	I	1	1979	1740	2.98

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=5
(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
VANADIUM	MG/H	696000	MG/H	2086	643	M5	MH	14	I	1	1979	1740	2.98
CHROMIUM	MG/H	8700000	MG/H	28012	643	M5	MH	14	I	1	1979	1740	2.98
MANGANESE	MG/H	4002000	MG/H	4768	643	M5	MH	14	I	1	1979	1740	2.98
IRON	MG/H	295800000	MG/H	409750	643	M5	MH	14	I	1	1979	1740	2.98
COBALT	MG/H	522000	MG/H	1490	643	M5	MH	14	I	1	1979	1740	2.98
NICKEL	MG/H	2436000	MG/H	7152	643	M5	MH	14	I	1	1979	1740	2.98
COPPER	MG/H	13050000	MG/H	47084	643	M5	MH	14	I	1	1979	1740	2.98
ZINC	MG/H	19140000	MG/H	106684	643	M5	MH	14	I	1	1979	1740	2.98
SELENIUM	MG/H	ND	MG/H	1192	643	M5	MH	14	I	1	1979	1740	2.98
BROMINE	MG/H	ND	MG/H	3278	643	M5	MH	14	I	1	1979	1740	2.98
CADMIUM	MG/H	696000	MG/H	2086	643	M5	MH	14	I	1	1979	1740	2.98
TIN	MG/H	4350000	MG/H	71222	643	M5	MH	14	I	1	1979	1740	2.98
ANTIMONY	MG/H	348000	MG/H	1490	643	M5	MH	14	I	1	1979	1740	2.98
BARIUM	MG/H	7134000	MG/H	16688	643	M5	MH	14	I	1	1979	1740	2.98
LEAD	MG/H	8352000	MG/H	67646	643	M5	MH	14	I	1	1979	1740	2.98
SCRUBBER	%				787	M5	FB	15	I	1	1979		
SODIUM	MG/H	ND	MG/H	1842	787	M5	FB	15	I	1	1979	838	0.094
MAGNESIUM	MG/H	7290600	MG/H	949	787	M5	FB	15	I	1	1979	838	0.094
ALUMINUM	MG/H	33520000	MG/H	2886	787	M5	FB	15	I	1	1979	838	0.094
SILICON	MG/H	142460000	MG/H	5010	787	M5	FB	15	I	1	1979	838	0.094
PHOSPHORUS	MG/H	34358000	MG/H	3892	787	M5	FB	15	I	1	1979	838	0.094
SULFUR	MG/H	6871600	MG/H	13555	787	M5	FB	15	I	1	1979	838	0.094
CHLORINE	MG/H	ND	MG/H	874	787	M5	FB	15	I	1	1979	838	0.094
POTASSIUM	MG/H	10056000	MG/H	1006	787	M5	FB	15	I	1	1979	838	0.094
CALCIUM	MG/H	62850000	MG/H	8234	787	M5	FB	15	I	1	1979	838	0.094
TITANIUM	MG/H	6452600	MG/H	611	787	M5	FB	15	I	1	1979	838	0.094
VANADIUM	MG/H	251400	MG/H	169	787	M5	FB	15	I	1	1979	838	0.094
CHROMIUM	MG/H	1843600	MG/H	263	787	M5	FB	15	I	1	1979	838	0.094
MANGANESE	MG/H	2849200	MG/H	432	787	M5	FB	15	I	1	1979	838	0.094
IRON	MG/H	63688000	MG/H	4249	787	M5	FB	15	I	1	1979	838	0.094
COBALT	MG/H	83800	MG/H	ND	787	M5	FB	15	I	1	1979	838	0.094
NICKEL	MG/H	502800	MG/H	ND	787	M5	FB	15	I	1	1979	838	0.094
COPPER	MG/H	2262600	MG/H	263	787	M5	FB	15	I	1	1979	838	0.094
ZINC	MG/H	8380000	MG/H	1617	787	M5	FB	15	I	1	1979	838	0.094

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

------------------------------ REF=5 ------------------------------

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SELENIUM	MG/H	ND	MG/H	338	787	M5	FB	15	I	1	1979	838	0.094
BROMINE	MG/H	ND	MG/H	724	787	M5	FB	15	I	1	1979	838	0.094
CADMIUM	MG/H	670400	MG/H	122	787	M5	FB	15	I	1	1979	838	0.094
TIN	MG/H	2095000	MG/H	555	787	M5	FB	15	I	1	1979	838	0.094
ANTIMONY	MG/H	83800	MG/H	ND	787	M5	FB	15	I	1	1979	838	0.094
BARIUM	MG/H	3771000	MG/H	376	787	M5	FB	15	I	1	1979	838	0.094
LEAD	MG/H	494[illegible]00	MG/H	2124	787	M5	FB	15	I	1	1979	838	0.094
SCRUBBER	%	94.9				M5	MH	16	C	1	1980		
SODIUM	MG/H	ND	MG/H	7242		M5	MH	16	C	1	1980	1890	2.13
MAGNESIUM	MG/H	17388000	MG/H	639		M5	MH	16	C	1	1980	1890	2.13
ALUMINUM	MG/H	98280000	MG/H	1065		M5	MH	16	C	1	1980	1890	2.13
SILICON	MG/H	226800000	MG/H	19383		M5	MH	16	C	1	1980	1890	2.13
PHOSPHORUS	MG/H	69930000	MG/H	17892		M5	MH	16	C	1	1980	1890	2.13
SULFUR	MG/H	8883000	MG/H	81579		M5	MH	16	C	1	1980	1890	2.13
CHLORINE	MG/H	12852000	MG/H	61983		M5	MH	16	C	1	1980	1890	2.13
POTASSIUM	MG/H	20790000	MG/H	3834		M5	MH	16	C	1	1980	1890	2.13
CALCIUM	MG/H	185220000	MG/H	4899		M5	MH	16	C	1	1980	1890	2.13
TITANIUM	MG/H	22302000	MG/H	426		M5	MH	16	C	1	1980	1890	2.13
VANADIUM	MG/H	ND	MG/H	ND		M5	MH	16	C	1	1980	1890	2.13
CHROMIUM	MG/H	7182000	MG/H	7029		M5	MH	16	C	1	1980	1890	2.13
MANGANESE	MG/H	2079000	MG/H	213		M5	MH	16	C	1	1980	1890	2.13
IRON	MG/H	102060000	MG/H	7242		M5	MH	16	C	1	1980	1890	2.13
COBALT	MG/H	189000	MG/H	ND		M5	MH	16	C	1	1980	1890	2.13
NICKEL	MG/H	1134000	MG/H	ND		M5	MH	16	C	1	1980	1890	2.13
COPPER	MG/H	8316000	MG/H	16401		M5	MH	16	C	1	1980	1890	2.13
ZINC	MG/H	26460000	MG/H	57297		M5	MH	16	C	1	1980	1890	2.13
SELENIUM	MG/H	ND	MG/H	852		M5	MH	16	C	1	1980	1890	2.13
BROMINE	MG/H	ND	MG/H	5538		M5	MH	16	C	1	1980	1890	2.13
CADMIUM	MG/H	567000	MG/H	59001		M5	MH	16	C	1	1980	1890	2.13
TIN	MG/H	3591000	MG/H	24708		M5	MH	16	C	1	1980	1890	2.13
ANTIMONY	MG/H	189000	MG/H	1278		M5	MH	16	C	1	1980	1890	2.13
BARIUM	MG/H	5103000	MG/H	426		M5	MH	16	C	1	1980	1890	2.13
LEAD	MG/H	4347000	MG/H	66882		M5	MH	16	C	1	1980	1890	2.13

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=7

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ZINC	MG/H	174000	MG/H	ND	788	M5	FB	19	VI	1	1980		
COPPER	MG/H	126500	MG/H	125	788	M5	FB	19	VI	1	1980		
LEAD	MG/H	37550	MG/H	100	788	M5	FB	19	VI	1	1980		
CHROMIUM	MG/H	4600	MG/H	50	788	M5	FB	19	VI	1	1980		
NICKEL	MG/H	3075	MG/H	7.5	788	M5	FB	19	VI	1	1980		
CADMIUM	MG/H	525	MG/H	0.5	788	M5	FB	19	VI	1	1980		
ZINC	MG/H	137250	MG/H	ND	788	M5	FB	19	VI	2	1980		
COPPER	MG/H	104750	MG/H	25	788	M5	FB	19	VI	2	1980		
LEAD	MG/H	28175	MG/H	20	788	M5	FB	19	VI	2	1980		
CHROMIUM	MG/H	4075	MG/H	25	788	M5	FB	19	VI	2	1980		
NICKEL	MG/H	2900	MG/H	7.5	788	M5	FB	19	VI	2	1980		
CADMIUM	MG/H	325	MG/H	ND	788	M5	FB	19	VI	2	1980		
ZINC	MG/H	154178	MG/H	ND	788	M5	FB	19	VI	3	1980		
COPPER	MG/H	117511	MG/H	44	788	M5	FB	19	VI	3	1980		
LEAD	MG/H	33867	MG/H	89	788	M5	FB	19	VI	3	1980		
CHROMIUM	MG/H	3911	MG/H	18	788	M5	FB	19	VI	3	1980		
NICKEL	MG/H	2800	MG/H	ND	788	M5	FB	19	VI	3	1980		
CADMIUM	MG/H	489	MG/H	ND	788	M5	FB	19	VI	3	1980		
MERCURY	MG/H	800	MG/H	780	788	MM5	FB	19	VI	4	1980		

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=8 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	95.8			761	SASS	MH	20	VCI	2	1984		
ALUMINUM	MG/H	123728	MG/H	1228	761	SASS	MH	20	VCI	2	1984	209	0.074
ANTIMONY	MG/H	40337	MG/H	47	761	SASS	MH	20	VCI	2	1984	209	0.074
ARSENIC	MG/H	126236	MG/H	19	761	SASS	MH	20	VCI	2	1984	209	0.074
BARIUM	MG/H	12247	MG/H	99	761	SASS	MH	20	VCI	2	1984	209	0.074
CADMIUM	MG/H	45562	MG/H	730	761	SASS	MH	20	VCI	2	1984	209	0.074
CALCIUM	MG/H	11453200	MG/H	1236	761	SASS	MH	20	VCI	2	1984	209	0.074
CHROMIUM	MG/H	72314	MG/H	414	761	SASS	MH	20	VCI	2	1984	209	0.074
COBALT	MG/H	7461	MG/H	ND	761	SASS	MH	20	VCI	2	1984	209	0.074
COPPER	MG/H	988570	MG/H	347	761	SASS	MH	20	VCI	2	1984	209	0.074
GOLD	MG/H	1116	MG/H	ND	761	SASS	MH	20	VCI	2	1984	209	0.074
IRON	MG/H	13543200	MG/H	1739	761	SASS	MH	20	VCI	2	1984	209	0.074
LEAD	MG/H	130625	MG/H	317	761	SASS	MH	20	VCI	2	1984	209	0.074
MAGNESIUM	MG/H	3971000	MG/H	372	761	SASS	MH	20	VCI	2	1984	209	0.074
MANGANESE	MG/H	66462	MG/H	52	761	SASS	MH	20	VCI	2	1984	209	0.074
NICKEL	MG/H	29887	MG/H	537	761	SASS	MH	20	VCI	2	1984	209	0.074
PHOSPHORUS	MG/H	13668600	MG/H	689	761	SASS	MH	20	VCI	2	1984	209	0.074
SELENIUM	MG/H	159049	MG/H	69	761	SASS	MH	20	VCI	2	1984	209	0.074
SILVER	MG/H	ND	MG/H	12	761	SASS	MH	20	VCI	2	1984	209	0.074
SODIUM	MG/H	1406570	MG/H	8140	761	SASS	MH	20	VCI	2	1984	209	0.074
SULFUR	MG/H	4598000	MG/H	15910	761	SASS	MH	20	VCI	2	1984	209	0.074
TIN	MG/H	51205	MG/H	87	761	SASS	MH	20	VCI	2	1984	209	0.074
TITANIUM	MG/H	1540330	MG/H	37	761	SASS	MH	20	VCI	2	1984	209	0.074
VANADIUM	MG/H	96558	MG/H	122	761	SASS	MH	20	VCI	2	1984	209	0.074
ZINC	MG/H	1270720	MG/H	1317	761	SASS	MH	20	VCI	2	1984	209	0.074
SCRUBBER	%	95.1			748	SASS	MH	20	VCI	3	1984		
ALUMINUM	MG/H	159517	MG/H	12852	748	SASS	MH	20	VCI	3	1984	269	0.084
ANTIMONY	MG/H	58373	MG/H	51	748	SASS	MH	20	VCI	3	1984	269	0.084
ARSENIC	MG/H	149026	MG/H	68	748	SASS	MH	20	VCI	3	1984	269	0.084
BARIUM	MG/H	24318	MG/H	30	748	SASS	MH	20	VCI	3	1984	269	0.084
CADMIUM	MG/H	63753	MG/H	2100	748	SASS	MH	20	VCI	3	1984	269	0.084
CALCIUM	MG/H	14526000	MG/H	2428	748	SASS	MH	20	VCI	3	1984	269	0.084
CHROMIUM	MG/H	104103	MG/H	204	748	SASS	MH	20	VCI	3	1984	269	0.084
COBALT	MG/H	10222	MG/H	ND	748	SASS	MH	20	VCI	3	1984	269	0.084
COPPER	MG/H	1229330	MG/H	701	748	SASS	MH	20	VCI	3	1984	269	0.084

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=8

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
GOLD	MG/H	1167	MG/H	ND	748	SASS	MH	20	VCI	3	1984	269	0.084
IRON	MG/H	16920100	MG/H	1445	748	SASS	MH	20	VCI	3	1984	269	0.084
LEAD	MG/H	188569	MG/H	1260	748	SASS	MH	20	VCI	3	1984	269	0.084
MAGNESIUM	MG/H	5595200	MG/H	87	748	SASS	MH	20	VCI	3	1984	269	0.084
MANGANESE	MG/H	87694	MG/H	62	748	SASS	MH	20	VCI	3	1984	269	0.084
NICKEL	MG/H	50572	MG/H	433	748	SASS	MH	20	VCI	3	1984	269	0.084
PHOSPHORUS	MG/H	15736500	MG/H	597	748	SASS	MH	20	VCI	3	1984	269	0.084
SELENIUM	MG/H	ND	MG/H	26	748	SASS	MH	20	VCI	3	1984	269	0.084
SILVER	MG/H	4761	MG/H	26	748	SASS	MH	20	VCI	3	1984	269	0.084
SODIUM	MG/H	629460	MG/H	1999	748	SASS	MH	20	VCI	3	1984	269	0.084
SULFUR	MG/H	6402200	MG/H	29904	748	SASS	MH	20	VCI	3	1984	269	0.084
TIN	MG/H	76396	MG/H	391	748	SASS	MH	20	VCI	3	1984	269	0.084
TITANIUM	MG/H	1866860	MG/H	46	748	SASS	MH	20	VCI	3	1984	269	0.084
VANADIUM	MG/H	126699	MG/H	368	748	SASS	MH	20	VCI	3	1984	269	0.084
ZINC	MG/H	1778090	MG/H	1000	748	SASS	MH	20	VCI	3	1984	269	0.084

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=9

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	98.4			726	SASS	MH	20	VCI	1	1985		
ALUMINUM	MG/H	7946400	MG/H	39420	726	SASS	MH	20	VCI	1	1985	264	0.054
ANTIMONY	MG/H	39600	MG/H	37	726	SASS	MH	20	VCI	1	1985	264	0.054
ARSENIC	MG/H	185856	MG/H	198	726	SASS	MH	20	VCI	1	1985	264	0.054
BARIUM	MG/H	691680	MG/H	1193	726	SASS	MH	20	VCI	1	1985	264	0.054
CADMIUM	MG/H	76032	MG/H	1658	726	SASS	MH	20	VCI	1	1985	264	0.054
CALCIUM	MG/H	13728000	MG/H	39096	726	SASS	MH	20	VCI	1	1985	264	0.054
CHROMIUM	MG/H	195624	MG/H	1280	726	SASS	MH	20	VCI	1	1985	264	0.054
COBALT	MG/H	16500	MG/H	10	726	SASS	MH	20	VCI	1	1985	264	0.054
COPPER	MG/H	1386000	MG/H	2284	726	SASS	MH	20	VCI	1	1985	264	0.054
GOLD	MG/H	ND	MG/H	ND	726	SASS	MH	20	VCI	1	1985	264	0.054
IRON	MG/H	14572800	MG/H	11880	726	SASS	MH	20	VCI	1	1985	264	0.054
LEAD	MG/H	248160	MG/H	691	726	SASS	MH	20	VCI	1	1985	264	0.054
MAGNESIUM	MG/H	5887200	MG/H	1296	726	SASS	MH	20	VCI	1	1985	264	0.054
MANGANESE	MG/H	105864	MG/H	180	726	SASS	MH	20	VCI	1	1985	264	0.054
NICKEL	MG/H	86328	MG/H	65	726	SASS	MH	20	VCI	1	1985	264	0.054
PHOSPHORUS	MG/H	14599200	MG/H	3391	726	SASS	MH	20	VCI	1	1985	264	0.054
SELENIUM	MG/H	ND	MG/H	3	726	SASS	MH	20	VCI	1	1985	264	0.054
SILVER	MG/H	ND	MG/H	17	726	SASS	MH	20	VCI	1	1985	264	0.054
SODIUM	MG/H	1998480	MG/H	4779	726	SASS	MH	20	VCI	1	1985	264	0.054
SULFUR	MG/H	4910400	MG/H	52272	726	SASS	MH	20	VCI	1	1985	264	0.054
TIN	MG/H	123288	MG/H	2678	726	SASS	MH	20	VCI	1	1985	264	0.054
TITANIUM	MG/H	1879680	MG/H	2236	726	SASS	MH	20	VCI	1	1985	264	0.054
VANADIUM	MG/H	51480	MG/H	44	726	SASS	MH	20	VCI	1	1985	264	0.054
ZINC	MG/H	1734480	MG/H	3731	726	SASS	MH	20	VCI	1	1985	264	0.054
SCRUBBER	%	98.5			747	SASS	MH	20	VCI	2	1985		
ALUMINUM	MG/H	9549900	MG/H	29677	747	SASS	MH	20	VCI	2	1985	243	0.059
ANTIMONY	MG/H	32805	MG/H	36	747	SASS	MH	20	VCI	2	1985	243	0.059
ARSENIC	MG/H	166455	MG/H	137	747	SASS	MH	20	VCI	2	1985	243	0.059
BARIUM	MG/H	566190	MG/H	979	747	SASS	MH	20	VCI	2	1985	243	0.059
CADMIUM	MG/H	52002	MG/H	2696	747	SASS	MH	20	VCI	2	1985	243	0.059
CALCIUM	MG/H	16013700	MG/H	40238	747	SASS	MH	20	VCI	2	1985	243	0.059
CHROMIUM	MG/H	176904	MG/H	6018	747	SASS	MH	20	VCI	2	1985	243	0.059
COBALT	MG/H	13462	MG/H	33	747	SASS	MH	20	VCI	2	1985	243	0.059
COPPER	MG/H	1232010	MG/H	4183	747	SASS	MH	20	VCI	2	1985	243	0.059

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=9 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
GOLD	MG/H	238	MG/H	1	747	SASS	MH	20	VCI	2	1985	243	0.059
IRON	MG/H	14239800	MG/H	38704	747	SASS	MH	20	VCI	2	1985	243	0.059
LEAD	MG/H	247860	MG/H	4714	747	SASS	MH	20	VCI	2	1985	243	0.059
MAGNESIUM	MG/H	5977800	MG/H	1634	747	SASS	MH	20	VCI	2	1985	243	0.059
MANGANESE	MG/H	106677	MG/H	690	747	SASS	MH	20	VCI	2	1985	243	0.059
NICKEL	MG/H	59292	MG/H	2820	747	SASS	MH	20	VCI	2	1985	243	0.059
PHOSPHORUS	MG/H	13170600	MG/H	820	747	SASS	MH	20	VCI	2	1985	243	0.059
SELENIUM	MG/H	ND	MG/H	3770	747	SASS	MH	20	VCI	2	1985	243	0.059
SILVER	MG/H	ND	MG/H	15	747	SASS	MH	20	VCI	2	1985	243	0.059
SODIUM	MG/H	1866240	MG/H	7965	747	SASS	MH	20	VCI	2	1985	243	0.059
SULFUR	MG/H	5005800	MG/H	79060	747	SASS	MH	20	VCI	2	1985	243	0.059
TIN	MG/H	101574	MG/H	3375	747	SASS	MH	20	VCI	2	1985	243	0.059
TITANIUM	MG/H	1562490	MG/H	814	747	SASS	MH	20	VCI	2	1985	243	0.059
VANADIUM	MG/H	50058	MG/H	267	747	SASS	MH	20	VCI	2	1985	243	0.059
ZINC	MG/H	1807920	MG/H	5304	747	SASS	MH	20	VCI	2	1985	243	0.059
SCRUBBER	%	97.6			774	SASS	MH	20	VCI	3	1985		
ALUMINUM	MG/H	11954800	MG/H	167240	774	SASS	MH	20	VCI	3	1985	242	0.113
ANTIMONY	MG/H	18174	MG/H	79	774	SASS	MH	20	VCI	3	1985	242	0.113
ARSENIC	MG/H	193116	MG/H	314	774	SASS	MH	20	VCI	3	1985	242	0.113
BARIUM	MG/H	573540	MG/H	2735	774	SASS	MH	20	VCI	3	1985	242	0.113
CADMIUM	MG/H	47190	MG/H	1356	774	SASS	MH	20	VCI	3	1985	242	0.113
CALCIUM	MG/H	19093800	MG/H	273460	774	SASS	MH	20	VCI	3	1985	242	0.113
CHROMIUM	MG/H	208362	MG/H	7	774	SASS	MH	20	VCI	3	1985	242	0.113
COBALT	MG/H	13237	MG/H	2	774	SASS	MH	20	VCI	3	1985	242	0.113
COPPER	MG/H	1372140	MG/H	1480	774	SASS	MH	20	VCI	3	1985	242	0.113
GOLD	MG/H	ND	MG/H	ND	774	SASS	MH	20	VCI	3	1985	242	0.113
IRON	MG/H	16214000	MG/H	1695	774	SASS	MH	20	VCI	3	1985	242	0.113
LEAD	MG/H	244420	MG/H	2079	774	SASS	MH	20	VCI	3	1985	242	0.113
MAGNESIUM	MG/H	5808000	MG/H	1526	774	SASS	MH	20	VCI	3	1985	242	0.113
MANGANESE	MG/H	118580	MG/H	0.0007	774	SASS	MH	20	VCI	3	1985	242	0.113
NICKEL	MG/H	471900	MG/H	4	774	SASS	MH	20	VCI	3	1985	242	0.113
PHOSPHORUS	MG/H	12438800	MG/H	3017	774	SASS	MH	20	VCI	3	1985	242	0.113
SELENIUM	MG/H	ND	MG/H	13	774	SASS	MH	20	VCI	3	1985	242	0.113
SILVER	MG/H	ND	MG/H	38	774	SASS	MH	20	VCI	3	1985	242	0.113

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=9

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SODIUM	MG/H	2008600	MG/H	82	774	SASS	MH	20	VCI	3	1985	242	0.113
SULFUR	MG/H	4694800	MG/H	16046	774	SASS	MH	20	VCI	3	1985	242	0.113
TIN	MG/H	106238	MG/H	681	774	SASS	MH	20	VCI	3	1985	242	0.113
TITANIUM	MG/H	1853720	MG/H	405	774	SASS	MH	20	VCI	3	1985	242	0.113
VANADIUM	MG/H	56870	MG/H	47	774	SASS	MH	20	VCI	3	1985	242	0.113
ZINC	MG/H	1848880	MG/H	1153	774	SASS	MH	20	VCI	3	1985	242	0.113

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=10

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
CADMIUM	MG/H	6468	MG/H	2052		M5	MH	21		1	1985	1320	0.925
LEAD	MG/H	127380	MG/H	11088		M5	MH	21		1	1985	1320	0.925
MERCURY	MG/H	620	MG/H	270		M5	MH	21		1	1985	1320	0.925
CADMIUM	MG/H	5772	MG/H	3780		M5	MH	21		2	1985	1178	0.594
LEAD	MG/H	113677	MG/H	61920		M5	MH	21		2	1985	1178	0.594
MERCURY	MG/H	554	MG/H	2808		M5	MH	21		2	1985	1178	0.594
CADMIUM	MG/H	6257	MG/H	3780		M5	MH	21		3	1985	1277	0.612
LEAD	MG/H	123231	MG/H	35676		M5	MH	21		3	1985	1277	0.612
MERCURY	MG/H	600	MG/H	4284		M5	MH	21		3	1985	1277	0.612
CADMIUM	MG/H	5772	MG/H	3888		M5	MH	21		4	1985	1178	0.934
LEAD	MG/H	113677	MG/H	81360		M5	MH	21		4	1985	1178	0.934
MERCURY	MG/H	554	MG/H	2988		M5	MH	21		4	1985	1178	0.934
CADMIUM	MG/H	5777	MG/H	1476		M5	MH	21		5	1985	1179	0.576
LEAD	MG/H	113774	MG/H	14112		M5	MH	21		5	1985	1179	0.576
MERCURY	MG/H	554	MG/H	1224		M5	MH	21		5	1985	1179	0.576
CADMIUM	MG/H	5282	MG/H	2376		M5	MH	21		6	1985	1078	0.753
LEAD	MG/H	104027	MG/H	18576		M5	MH	21		6	1985	1078	0.753
MERCURY	MG/H	507	MG/H	1692		M5	MH	21		6	1985	1078	0.753
CADMIUM	MG/H	5219	MG/H	1548		M5	MH	21		7	1985	1065	0.603
LEAD	MG/H	102773	MG/H	34884		M5	MH	21		7	1985	1065	0.603
MERCURY	MG/H	501	MG/H	2160		M5	MH	21		7	1985	1065	0.603

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=11

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	98.2				SASS	MH	2	I	1	1979		
SILVER	MG/H	28182	MG/H	424		SASS	MH	2	I	1	1979	1281	0.918
CADMIUM	MG/H	43554	MG/H	5556		SASS	MH	2	I	1	1979	1281	0.918
CHROMIUM	MG/H	1813896	MG/H	2080		SASS	MH	2	I	1	1979	1281	0.918
COPPER	MG/H	2578653	MG/H	7392		SASS	MH	2	I	1	1979	1281	0.918
IRON	MG/H	16131633	MG/H	14913		SASS	MH	2	I	1	1979	1281	0.918
MANGANESE	MG/H	666120	MG/H	453		SASS	MH	2	I	1	1979	1281	0.918
NICKEL	MG/H	1015833	MG/H	1769		SASS	MH	2	I	1	1979	1281	0.918
LEAD	MG/H	2408280	MG/H	41420		SASS	MH	2	I	1	1979	1281	0.918
ZINC	MG/H	2946300	MG/H	9290		SASS	MH	2	I	1	1979	1281	0.918
SCRUBBER	%	92.3				SASS	MH	3	I	1	1979		
SILVER	MG/H	105522	MG/H	739		SASS	MH	3	I	1	1979	2441	1.63
CADMIUM	MG/H	346622	MG/H	62494		SASS	MH	3	I	1	1979	2441	1.63
CHROMIUM	MG/H	2228633	MG/H	4762		SASS	MH	3	I	1	1979	2441	1.63
COPPER	MG/H	2489820	MG/H	7980		SASS	MH	3	I	1	1979	2441	1.63
IRON	MG/H	168673100	MG/H	23653		SASS	MH	3	I	1	1979	2441	1.63
MANGANESE	MG/H	1384047	MG/H	453		SASS	MH	3	I	1	1979	2441	1.63
NICKEL	MG/H	3449133	MG/H	2349		SASS	MH	3	I	1	1979	2441	1.63
LEAD	MG/H	1789253	MG/H	32259		SASS	MH	3	I	1	1979	2441	1.63
ZINC	MG/H	9781087	MG/H	79030		SASS	MH	3	I	1	1979	2441	1.63
SCRUBBER	%	99.2				SASS	MH	4	I	1	1979		
SILVER	MG/H	63342	MG/H	1184		SASS	MH	4	I	1	1979	1173	2.03
CADMIUM	MG/H	8211	MG/H	2046		SASS	MH	4	I	1	1979	1173	2.03
CHROMIUM	MG/H	480930	MG/H	2663		SASS	MH	4	I	1	1979	1173	2.03
COPPER	MG/H	876231	MG/H	11525		SASS	MH	4	I	1	1979	1173	2.03
IRON	MG/H	22623651	MG/H	16053		SASS	MH	4	I	1	1979	1173	2.03
MANGANESE	MG/H	353073	MG/H	3300		SASS	MH	4	I	1	1979	1173	2.03
NICKEL	MG/H	330786	MG/H	1889		SASS	MH	4	I	1	1979	1173	2.03
LEAD	MG/H	289731	MG/H	55155		SASS	MH	4	I	1	1979	1173	2.03
ZINC	MG/H	679167	MG/H	44664		SASS	MH	4	I	1	1979	1173	2.03
SCRUBBER	%	94.7				SASS	MH	5	VI	1	1979		
SILVER	MG/H	36708	MG/H	90		SASS	MH	5	VI	1	1979	1596	0.205
CADMIUM	MG/H	17556	MG/H	654		SASS	MH	5	VI	1	1979	1596	0.205
CHROMIUM	MG/H	734160	MG/H	170		SASS	MH	5	VI	1	1979	1596	0.205
COPPER	MG/H	2296644	MG/H	737		SASS	MH	5	VI	1	1979	1596	0.205

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=11 --

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
IRON	MG/H	145395600	MG/H	1681		SASS	MH	5	VI	1	1979	1596	0.205
MANGANESE	MG/H	2014152	MG/H	49		SASS	MH	5	VI	1	1979	1596	0.205
NICKEL	MG/H	1372560	MG/H	115		SASS	MH	5	VI	1	1979	1596	0.205
LEAD	MG/H	1197000	MG/H	30750		SASS	MH	5	VI	1	1979	1596	0.205
ZINC	MG/H	7043148	MG/H	13570		SASS	MH	5	VI	1	1979	1596	0.205
SCRUBBER	%	89.5				SASS	MH	6	VI	1	1979		
SILVER	MG/H	18720	MG/H	272		SASS	MH	6	VI	1	1979	936	0.555
CADMIUM	MG/H	6552	MG/H	210		SASS	MH	6	VI	1	1979	936	0.555
CHROMIUM	MG/H	171288	MG/H	406		SASS	MH	6	VI	1	1979	936	0.555
COPPER	MG/H	277992	MG/H	973		SASS	MH	6	VI	1	1979	936	0.555
IRON	MG/H	47049912	MG/H	10043		SASS	MH	6	VI	1	1979	936	0.555
MANGANESE	MG/H	322920	MG/H	96		SASS	MH	6	VI	1	1979	936	0.555
NICKEL	MG/H	113256	MG/H	83		SASS	MH	6	VI	1	1979	936	0.555
LEAD	MG/H	199368	MG/H	5793		SASS	MH	6	VI	1	1979	936	0.555
ZINC	MG/H	811512	MG/H	2647		SASS	MH	6	VI	1	1979	936	0.555
SCRUBBER	%	99.6				SASS	FB	8	VI	1	1979		
SILVER	MG/H	103180	MG/H	7.5		SASS	FB	8	VI	1	1979	1340	0.049
CADMIUM	MG/H	14740	MG/H	2.5		SASS	FB	8	VI	1	1979	1340	0.049
CHROMIUM	MG/H	113900	MG/H	24		SASS	FB	8	VI	1	1979	1340	0.049
COPPER	MG/H	950060	MG/H	19		SASS	FB	8	VI	1	1979	1340	0.049
IRON	MG/H	13239200	MG/H	731		SASS	FB	8	VI	1	1979	1340	0.049
MANGANESE	MG/H	1440500	MG/H	14		SASS	FB	8	VI	1	1979	1340	0.049
NICKEL	MG/H	143380	MG/H	42		SASS	FB	8	VI	1	1979	1340	0.049
LEAD	MG/H	493120	MG/H	353		SASS	FB	8	VI	1	1979	1340	0.049
ZINC	MG/H	1120240	MG/H	78		SASS	MH	8	VI	1	1979	1340	0.049
SCRUBBER	%	85.1				SASS	MH	9	C	1	1979		
SILVER	MG/H	949	MG/H	271		SASS	MH	9	C	1	1979	73	2.45
CADMIUM	MG/H	949	MG/H	567		SASS	MH	9	C	1	1979	73	2.45
CHROMIUM	MG/H	18615	MG/H	2062		SASS	MH	9	C	1	1979	73	2.45
COPPER	MG/H	54531	MG/H	4209		SASS	MH	9	C	1	1979	73	2.45
IRON	MG/H	675688	MG/H	11339		SASS	MH	9	C	1	1979	73	2.45
MANGANESE	MG/H	46063	MG/H	278		SASS	MH	9	C	1	1979	73	2.45
NICKEL	MG/H	9490	MG/H	618		SASS	MH	9	C	1	1979	73	2.45

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=11

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
LEAD	MG/H	63291	MG/H	41633		SASS	MH	9	C	1	1979	73	2.45
ZINC	MG/H	206371	MG/H	25627		SASS	MH	9	C	1	1979	73	2.45

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=12

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
SCRUBBER	%	98.5			785	M5	MH	24	I	1	1985		
CHROMIUM	MG/H	2039824	MG/H	2.0	785	M5	MH	24	I	1	1985	2435	1.4
SCRUBBER	%	98.2			777	M5	MH	24	I	2	1985		
CHROMIUM	MG/H	2379987	MG/H	2.0	777	M5	MH	24	I	2	1985	2372	1.6
SCRUBBER	%	98.8			744	M5	MH	24	I	3	1985		
CHROMIUM	MG/H	2409924	MG/H	3.0	744	M5	MH	24	I	3	1985	2761	1.1
SCRUBBER	%	99.0			761	M5	MH	24	I	4	1985		
CHROMIUM	MG/H	1867521	MG/H	2.0	761	M5	MH	24	I	4	1985	3139	1.0

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=13 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	ND	MG/H	76	829	M12S	MH	25	I	1	1987	734	5.83
BERYLLIUM	MG/H	ND	MG/H	ND	829	M12S	MH	25	I	1	1987	734	5.83
CADMIUM	MG/H	1200	MG/H	510	829	M12S	MH	25	I	1	1987	734	5.83
CHROMIUM	MG/H	131000	MG/H	739	829	M12S	MH	25	I	1	1987	734	5.83
LEAD	MG/H	67800	MG/H	20400	829	M12S	MH	25	I	1	1987	734	5.83
NICKEL	MG/H	14800	MG/H	280	829	M12S	MH	25	I	1	1987	734	5.83
ARSENIC	MG/H	ND	MG/H	54	829	M12S	MH	25	I	2	1987	653	4.80
BERYLLIUM	MG/H	ND	MG/H	ND	829	M12S	MH	25	I	2	1987	653	4.80
CADMIUM	MG/H	1900	MG/H	383	829	M12S	MH	25	I	2	1987	653	4.80
CHROMIUM	MG/H	141000	MG/H	204	829	M12S	MH	25	I	2	1987	653	4.80
LEAD	MG/H	76900	MG/H	17900	829	M12S	MH	25	I	2	1987	653	4.80
NICKEL	MG/H	15800	MG/H	204	829	M12S	MH	25	I	2	1987	653	4.80
ARSENIC	MG/H	ND	MG/H	49	823	M12S	MH	25	I	3	1987	764	4.47
BERYLLIUM	MG/H	600	MG/H	ND	823	M12S	MH	25	I	3	1987	764	4.47
CADMIUM	MG/H	ND	MG/H	376	823	M12S	MH	25	I	3	1987	764	4.47
CHROMIUM	MG/H	161000	MG/H	1880	823	M12S	MH	25	I	3	1987	764	4.47
LEAD	MG/H	67100	MG/H	16100	823	M12S	MH	25	I	3	1987	764	4.47
NICKEL	MG/H	14800	MG/H	9900	823	M12S	MH	25	I	3	1987	764	4.47
ARSENIC	MG/H	ND	MG/H	41	826	M12S	MH	25	I	4	1987	517	2.99
BERYLLIUM	MG/H	500	MG/H	ND	826	M12S	MH	25	I	4	1987	517	2.99
CADMIUM	MG/H	ND	MG/H	290	826	M12S	MH	25	I	4	1987	517	2.99
CHROMIUM	MG/H	123000	MG/H	218	826	M12S	MH	25	I	4	1987	517	2.99
LEAD	MG/H	51800	MG/H	12100	826	M12S	MH	25	I	4	1987	517	2.99
NICKEL	MG/H	8800	MG/H	290	826	M12S	MH	25	I	4	1987	517	2.99
ARSENIC	MG/H	ND	MG/H	101	823	M12L	MH	25	I	5	1987	695	3.37
BERYLLIUM	MG/H	ND	MG/H	ND	823	M12L	MH	25	I	5	1987	695	3.37
CADMIUM	MG/H	ND	MG/H	552	823	M12L	MH	25	I	5	1987	695	3.37
CHROMIUM	MG/H	137000	MG/H	444	823	M12L	MH	25	I	5	1987	695	3.37
LEAD	MG/H	71100	MG/H	22300	823	M12L	MH	25	I	5	1987	695	3.37
NICKEL	MG/H	14900	MG/H	111	823	M12L	MH	25	I	5	1987	695	3.37
ARSENIC	MG/H	ND	MG/H	111	826	M12L	MH	25	I	6	1987	884	4.64
BERYLLIUM	MG/H	ND	MG/H	ND	826	M12L	MH	25	I	6	1987	884	4.64
CADMIUM	MG/H	2200	MG/H	514	826	M12L	MH	25	I	6	1987	884	4.64
CHROMIUM	MG/H	189000	MG/H	251	826	M12L	MH	25	I	6	1987	884	4.64
LEAD	MG/H	77600	MG/H	33100	826	M12L	MH	25	I	6	1987	884	4.64

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

--- REF=13 ---
(continued)

	FEED		EMISS				INCIN	INCIN	AIR POLL CONTROL	SAMP			
POLLUTANT	UNIT	FEED	UNIT	EMISS	TEMP	METHOD	TYPE	ID	DEV	ID	YEAR	SLUDGE	PART
NICKEL	MG/H	15000	MG/H	280	826	M12L	MH	25	I	6	1987	884	4.64
ARSENIC	MG/H	ND	MG/H	99	797	M12L	MH	25	I	7	1987	627	3.66
BERYLLIUM	MG/H	500	MG/H	ND	797	M12L	MH	25	I	7	1987	627	3.66
CADMIUM	MG/H	1800	MG/H	716	797	M12L	MH	25	I	7	1987	627	3.66
CHROMIUM	MG/H	152000	MG/H	256	797	M12L	MH	25	I	7	1987	627	3.66
LEAD	MG/H	67300	MG/H	37300	797	M12L	MH	25	I	7	1987	627	3.66
NICKEL	MG/H	10900	MG/H	ND	797	M12L	MH	25	I	7	1987	627	3.66

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=14 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	9900	MG/H	498	903	M12S	MH	26	VI	1	1987	1351	0.48
BERYLLIUM	MG/H	430	MG/H	ND	903	M12S	MH	26	VI	1	1987	1351	0.48
CADMIUM	MG/H	12000	MG/H	1799	903	M12S	MH	26	VI	1	1987	1351	0.48
CHROMIUM	MG/H	105000	MG/H	417	903	M12S	MH	26	VI	1	1987	1351	0.48
LEAD	MG/H	143000	MG/H	4979	903	M12S	MH	26	VI	1	1987	1351	0.48
NICKEL	MG/H	110000	MG/H	671	903	M12S	MH	26	VI	1	1987	1351	0.48
SCRUBBER	%	96.5			903	M12S	MH	26	VI	1	1987	1351	0.48
ARSENIC	MG/H	9300	MG/H	462	889	M12S	MH	26	VI	2	1987	1313	0.51
BERYLLIUM	MG/H	400	MG/H	ND	889	M12S	MH	26	VI	2	1987	1313	0.51
CADMIUM	MG/H	11000	MG/H	1779	889	M12S	MH	26	VI	2	1987	1313	0.51
CHROMIUM	MG/H	112000	MG/H	3086	889	M12S	MH	26	VI	2	1987	1313	0.51
LEAD	MG/H	134000	MG/H	4222	889	M12S	MH	26	VI	2	1987	1313	0.51
NICKEL	MG/H	120000	MG/H	7378	889	M12S	MH	26	VI	2	1987	1313	0.51
SCRUBBER	%	95.5			889	M12S	MH	26	VI	2	1987	1313	0.51
ARSENIC	MG/H	8800	MG/H	446	889	M12S	MH	26	VI	3	1987	1250	0.58
BERYLLIUM	MG/H	430	MG/H	ND	889	M12S	MH	26	VI	3	1987	1250	0.58
CADMIUM	MG/H	11000	MG/H	2435	889	M12S	MH	26	VI	3	1987	1250	0.58
CHROMIUM	MG/H	109000	MG/H	2342	889	M12S	MH	26	VI	3	1987	1250	0.58
LEAD	MG/H	129000	MG/H	3409	889	M12S	MH	26	VI	3	1987	1250	0.58
NICKEL	MG/H	116000	MG/H	6186	889	M12S	MH	26	VI	3	1987	1250	0.58
SCRUBBER	%	95.2			889	M12S	MH	26	VI	3	1987	1250	0.58
ARSENIC	MG/H	7800	MG/H	394	834	M12S	MH	26	VI	4	1987	1324	0.50
BERYLLIUM	MG/H	470	MG/H	ND	834	M12S	MH	26	VI	4	1987	1324	0.50
CADMIUM	MG/H	11000	MG/H	2564	834	M12S	MH	26	VI	4	1987	1324	0.50
CHROMIUM	MG/H	110000	MG/H	747	834	M12S	MH	26	VI	4	1987	1324	0.50
LEAD	MG/H	134000	MG/H	4178	834	M12S	MH	26	VI	4	1987	1324	0.50
NICKEL	MG/H	116000	MG/H	2059	834	M12S	MH	26	VI	4	1987	1324	0.50
SCRUBBER	%	94.8			834	M12S	MH	26	VI	4	1987	1324	0.50
ARSENIC	MG/H	7600	MG/H	940	896	M12L	MH	26	VI	5	1987	1440	0.56
BERYLLIUM	MG/H	420	MG/H	ND	896	M12L	MH	26	VI	5	1987	1440	0.56
CADMIUM	MG/H	13700	MG/H	3200	896	M12L	MH	26	VI	5	1987	1440	0.56
CHROMIUM	MG/H	108000	MG/H	470	896	M12L	MH	26	VI	5	1987	1440	0.56
LEAD	MG/H	142000	MG/H	8900	896	M12L	MH	26	VI	5	1987	1440	0.56
NICKEL	MG/H	107000	MG/H	1800	896	M12L	MH	26	VI	5	1987	1440	0.56
SCRUBBER	%	95.8			896	M12L	MH	26	VI	5	1987	1440	0.56

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=14
(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	5300	MG/H	180	813	M12L	MH	26	VI	6	1987	1070	0.38
BERYLLIUM	MG/H	440	MG/H	ND	813	M12L	MH	26	VI	6	1987	1070	0.38
CADMIUM	MG/H	9800	MG/H	1900	813	M12L	MH	26	VI	6	1987	1070	0.38
CHROMIUM	MG/H	88100	MG/H	290	813	M12L	MH	26	VI	6	1987	1070	0.38
LEAD	MG/H	95900	MG/H	3000	813	M12L	MH	26	VI	6	1987	1070	0.38
NICKEL	MG/H	100000	MG/H	280	813	M12L	MH	26	VI	6	1987	1070	0.38
SCRUBBER	%	96.0			813	M12L	MH	26	VI	6	1987	1070	0.38
ARSENIC	MG/H	6900	MG/H	470	894	M12L	MH	26	VI	7	1987	1350	0.53
BERYLLIUM	MG/H	640	MG/H	1	894	M12L	MH	26	VI	7	1987	1350	0.53
CADMIUM	MG/H	11300	MG/H	2500	894	M12L	MH	26	VI	7	1987	1350	0.53
CHROMIUM	MG/H	113000	MG/H	1300	894	M12L	MH	26	VI	7	1987	1350	0.53
LEAD	MG/H	125000	MG/H	5800	894	M12L	MH	26	VI	7	1987	1350	0.53
NICKEL	MG/H	116000	MG/H	4200	894	M12L	MH	26	VI	7	1987	1350	0.53
SCRUBBER	%	94.4			894	M12L	MH	26	VI	7	1987	1350	0.53

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=15 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	23500	MG/H	30.7	766	M12	FB	27	VI	1	1987	830	0.411
BERYLLIUM	MG/H	600	MG/H	ND	766	M12	FB	27	VI	1	1987	830	0.411
CADMIUM	MG/H	5900	MG/H	240	766	M12	FB	27	VI	1	1987	830	0.411
CHROMIUM	MG/H	255000	MG/H	748	766	M12	FB	27	VI	1	1987	830	0.411
LEAD	MG/H	269000	MG/H	467	766	M12	FB	27	VI	1	1987	830	0.411
NICKEL	MG/H	1190000	MG/H	7406	766	M12	FB	27	VI	1	1987	830	0.411
ARSENIC	MG/H	28400	MG/H	26.1	768	M12	FB	27	VI	2	1987	1060	0.444
BERYLLIUM	MG/H	700	MG/H	ND	768	M12	FB	27	VI	2	1987	1060	0.444
CADMIUM	MG/H	7400	MG/H	237	768	M12	FB	27	VI	2	1987	1060	0.444
CHROMIUM	MG/H	316000	MG/H	940	768	M12	FB	27	VI	2	1987	1060	0.444
LEAD	MG/H	368000	MG/H	519	768	M12	FB	27	VI	2	1987	1060	0.444
NICKEL	MG/H	1310000	MG/H	6182	768	M12	FB	27	VI	2	1987	1060	0.444
ARSENIC	MG/H	24300	MG/H	23.7	768	M12	FB	27	VI	3	1987	1130	0.307
BERYLLIUM	MG/H	700	MG/H	ND	768	M12	FB	27	VI	3	1987	1130	0.307
CADMIUM	MG/H	6800	MG/H	339	768	M12	FB	27	VI	3	1987	1130	0.307
CHROMIUM	MG/H	277000	MG/H	475	768	M12	FB	27	VI	3	1987	1130	0.307
LEAD	MG/H	416000	MG/H	363	768	M12	FB	27	VI	3	1987	1130	0.307
NICKEL	MG/H	1130000	MG/H	4239	768	M12	FB	27	VI	3	1987	1130	0.307

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

-- REF=16 --

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
ARSENIC	MG/H	1500	MG/H	ND	676	M12	MH	28	VI	1	1987	574	0.91
BERYLLIUM	MG/H	170	MG/H	ND	676	M12	MH	28	VI	1	1987	574	0.91
CADMIUM	MG/H	4900	MG/H	1029	676	M12	MH	28	VI	1	1987	574	0.91
COPPER	MG/H	425000	MG/H	2063	676	M12	MH	28	VI	1	1987	574	0.91
LEAD	MG/H	138000	MG/H	7847	676	M12	MH	28	VI	1	1987	574	0.91
NICKEL	MG/H	161000	MG/H	345	676	M12	MH	28	VI	1	1987	574	0.91
SELENIUM	MG/H	460	MG/H	ND	676	M12	MH	28	VI	1	1987	574	0.91
ZINC	MG/H	344000	MG/H	15144	676	M12	MH	28	VI	1	1987	574	0.91
ARSENIC	MG/H	1500	MG/H	ND	766	M12	MH	28	VI	10	1987	570	0.55
BERYLLIUM	MG/H	170	MG/H	ND	766	M12	MH	28	VI	10	1987	570	0.55
CADMIUM	MG/H	8500	MG/H	1814	766	M12	MH	28	VI	10	1987	570	0.55
COPPER	MG/H	435000	MG/H	3672	766	M12	MH	28	VI	10	1987	570	0.55
LEAD	MG/H	209000	MG/H	28819	766	M12	MH	28	VI	10	1987	570	0.55
NICKEL	MG/H	164000	MG/H	157	766	M12	MH	28	VI	10	1987	570	0.55
SELENIUM	MG/H	730	MG/H	ND	766	M12	MH	28	VI	10	1987	570	0.55
ZINC	MG/H	350000	MG/H	34888	766	M12	MH	28	VI	10	1987	570	0.55
SCRUBBER	%	97.4			766	M12	MH	28	VI	10	1987	570	0.55
ARSENIC	MG/H	1300	MG/H	ND	932	M12	MH	28	VI	11	1987	575	0.85
BERYLLIUM	MG/H	170	MG/H	ND	932	M12	MH	28	VI	11	1987	575	0.85
CADMIUM	MG/H	8600	MG/H	1541	932	M12	MH	28	VI	11	1987	575	0.85
COPPER	MG/H	479000	MG/H	4512	932	M12	MH	28	VI	11	1987	575	0.85
LEAD	MG/H	205000	MG/H	22336	932	M12	MH	28	VI	11	1987	575	0.85
NICKEL	MG/H	177000	MG/H	249	932	M12	MH	28	VI	11	1987	575	0.85
SELENIUM	MG/H	680	MG/H	ND	932	M12	MH	28	VI	11	1987	575	0.85
ZINC	MG/H	371000	MG/H	37310	932	M12	MH	28	VI	11	1987	575	0.85
ARSENIC	MG/H	2100	MG/H	ND	799	M12	MH	28	VI	2	1987	642	0.41
BERYLLIUM	MG/H	190	MG/H	ND	799	M12	MH	28	VI	2	1987	642	0.41
CADMIUM	MG/H	7100	MG/H	1335	799	M12	MH	28	VI	2	1987	642	0.41
COPPER	MG/H	475000	MG/H	2559	799	M12	MH	28	VI	2	1987	642	0.41
LEAD	MG/H	186000	MG/H	13711	799	M12	MH	28	VI	2	1987	642	0.41
NICKEL	MG/H	135000	MG/H	146	799	M12	MH	28	VI	2	1987	642	0.41
SELENIUM	MG/H	580	MG/H	ND	799	M12	MH	28	VI	2	1987	642	0.41
ZINC	MG/H	404000	MG/H	17331	799	M12	MH	28	VI	2	1987	642	0.41
ARSENIC	MG/H	1900	MG/H	ND	718	M12	MH	28	VI	3	1987	694	0.38
BERYLLIUM	MG/H	180	MG/H	ND	718	M12	MH	28	VI	3	1987	694	0.38

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

--------------------------- REF=16 ---------------------------

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
CADMIUM	MG/H	6600	MG/H	1005	718	M12	MH	28	VI	3	1987	694	0.38
COPPER	MG/H	429000	MG/H	1790	718	M12	MH	28	VI	3	1987	694	0.38
LEAD	MG/H	163000	MG/H	8951	718	M12	MH	28	VI	3	1987	694	0.38
NICKEL	MG/H	127000	MG/H	183	718	M12	MH	28	VI	3	1987	694	0.38
SELENIUM	MG/H	540	MG/H	ND	718	M12	MH	28	VI	3	1987	694	0.38
ZINC	MG/H	375000	MG/H	11837	718	M12	MH	28	VI	3	1987	694	0.38
ARSENIC	MG/H	2200	MG/H	4	805	M12	MH	28	VI	4	1987	596	0.38
BERYLLIUM	MG/H	210	MG/H	ND	805	M12	MH	28	VI	4	1987	596	0.38
CADMIUM	MG/H	7600	MG/H	1775	805	M12	MH	28	VI	4	1987	596	0.38
COPPER	MG/H	500000	MG/H	5348	805	M12	MH	28	VI	4	1987	596	0.38
LEAD	MG/H	187000	MG/H	35682	805	M12	MH	28	VI	4	1987	596	0.38
NICKEL	MG/H	118000	MG/H	83	805	M12	MH	28	VI	4	1987	596	0.38
SELENIUM	MG/H	760	MG/H	ND	805	M12	MH	28	VI	4	1987	596	0.38
ZINC	MG/H	424000	MG/H	13035	805	M12	MH	28	VI	4	1987	596	0.38
ARSENIC	MG/H	1700	MG/H	ND	815	M12	MH	28	VI	5	1987	541	1.16
BERYLLIUM	MG/H	180	MG/H	ND	815	M12	MH	28	VI	5	1987	541	1.16
CADMIUM	MG/H	7700	MG/H	2018	815	M12	MH	28	VI	5	1987	541	1.16
COPPER	MG/H	501000	MG/H	3045	815	M12	MH	28	VI	5	1987	541	1.16
LEAD	MG/H	101000	MG/H	20449	815	M12	MH	28	VI	5	1987	541	1.16
NICKEL	MG/H	83000	MG/H	132	815	M12	MH	28	VI	5	1987	541	1.16
SELENIUM	MG/H	830	MG/H	ND	815	M12	MH	28	VI	5	1987	541	1.16
ZINC	MG/H	405000	MG/H	31299	815	M12	MH	28	VI	5	1987	541	1.16
ARSENIC	MG/H	1500	MG/H	ND	906	M12	MH	28	VI	6	1987	540	0.63
BERYLLIUM	MG/H	160	MG/H	ND	906	M12	MH	28	VI	6	1987	540	0.63
CADMIUM	MG/H	7600	MG/H	1153	906	M12	MH	28	VI	6	1987	540	0.63
COPPER	MG/H	449000	MG/H	3796	906	M12	MH	28	VI	6	1987	540	0.63
LEAD	MG/H	276000	MG/H	18273	906	M12	MH	28	VI	6	1987	540	0.63
NICKEL	MG/H	227000	MG/H	106	906	M12	MH	28	VI	6	1987	540	0.63
SELENIUM	MG/H	650	MG/H	ND	906	M12	MH	28	VI	6	1987	540	0.63
ZINC	MG/H	357000	MG/H	20721	906	M12	MH	28	VI	6	1987	540	0.63
ARSENIC	MG/H	1400	MG/H	2	901	M12	MH	28	VI	7	1987	530	0.59
BERYLLIUM	MG/H	160	MG/H	ND	901	M12	MH	28	VI	7	1987	530	0.59
CADMIUM	MG/H	8100	MG/H	1696	901	M12	MH	28	VI	7	1987	530	0.59
COPPER	MG/H	476000	MG/H	5962	901	M12	MH	28	VI	7	1987	530	0.59

TABLE 7. DATA BASE FOR DESCRIPTIVE STATISTICS

REF=16

(continued)

POLLUTANT	FEED UNIT	FEED	EMISS UNIT	EMISS	TEMP	METHOD	INCIN TYPE	INCIN ID	AIR POLL CONTROL DEV	SAMP ID	YEAR	SLUDGE	PART
LEAD	MG/H	205000	MG/H	49806	901	M12	MH	28	VI	7	1987	530	0.59
NICKEL	MG/H	238000	MG/H	500	901	M12	MH	28	VI	7	1987	530	0.59
SELENIUM	MG/H	760	MG/H	ND	901	M12	MH	28	VI	7	1987	530	0.59
ZINC	MG/H	378000	MG/H	32633	901	M12	MH	28	VI	7	1987	530	0.59
ARSENIC	MG/H	1300	MG/H	ND	774	M12	MH	28	VI	8	1987	544	0.85
BERYLLIUM	MG/H	160	MG/H	ND	774	M12	MH	28	VI	8	1987	544	0.85
CADMIUM	MG/H	8000	MG/H	1370	774	M12	MH	28	VI	8	1987	544	0.85
COPPER	MG/H	445000	MG/H	2740	774	M12	MH	28	VI	8	1987	544	0.85
LEAD	MG/H	201000	MG/H	15481	774	M12	MH	28	VI	8	1987	544	0.85
NICKEL	MG/H	180000	MG/H	107	774	M12	MH	28	VI	8	1987	544	0.85
SELENIUM	MG/H	740	MG/H	ND	774	M12	MH	28	VI	8	1987	544	0.85
ZINC	MG/H	366000	MG/H	27546	774	M12	MH	28	VI	8	1987	544	0.85
SCRUBBER	%	96.9			774	M12	MH	28	VI	8	1987	544	0.85
ARSENIC	MG/H	1400	MG/H	4	814	M12	MH	28	VI	9	1987	565	0.69
BERYLLIUM	MG/H	160	MG/H	ND	814	M12	MH	28	VI	9	1987	565	0.69
CADMIUM	MG/H	8200	MG/H	1720	814	M12	MH	28	VI	9	1987	565	0.69
COPPER	MG/H	457000	MG/H	4049	814	M12	MH	28	VI	9	1987	565	0.69
LEAD	MG/H	196000	MG/H	20223	814	M12	MH	28	VI	9	1987	565	0.69
NICKEL	MG/H	201000	MG/H	196	814	M12	MH	28	VI	9	1987	565	0.69
SELENIUM	MG/H	760	MG/H	ND	814	M12	MH	28	VI	9	1987	565	0.69
ZINC	MG/H	359000	MG/H	35300	814	M12	MH	28	VI	9	1987	565	0.69
SCRUBBER	%	96.8			814	M12	MH	28	VI	9	1987	565	0.69

5. SUMMARY STATISTICS

Tables 8, 9, and 10 present metal-specific summary statistics on incinerator destruction efficiencies for three levels of data aggregation:

- By incinerators within reference document (Table 8)
- Across incinerators within reference document (Table 9)
- Across incinerators and reference documents (Table 10).

The results of Table 8 are derived from individual destruction efficiency measurements, defined by:

$$100 - \left(\frac{\text{emissions concentration (mg/h)}}{\text{feed concentration (mg/h)}} \times 100\right)$$

Tables 9 and 10 present statistics based on the Table 8 mean incinerator efficiencies for specific metals across incinerators within individual reference, and across incinerators and references, respectively.

The treatment of nondetections (ND) in computations of destruction efficiencies is as follows:

- Observations with a nondetected feed concentration were excluded from the analyses
- Emission rates were set to zero for those measurements having a quantified feed and a nondetection for the corresponding rate, resulting in a destruction efficiency of 100%.

The summary statistics are presented in tables with a common format comprised of number of observations, minimum, mean, median, maximum, standard deviation, and nonparametric lower 5th and 10th percentiles by metal for Tables 8, 9, and 10. Table 10 includes 3 additional statistics--lognormal distribution estimates of the 10th, 25th, and 50th (median) percentiles.

Nonparametric estimates of the 5th and 10th percentiles are provided only in case there are 20 and 10 observations included in the analysis, respectively. Nonparametric medians and 5th and 10th percentiles were estimated using SAS Definition 1. Specifically, for the p^{th} percentile with n observations included in the analysis, the estimate of the p^{th} percentile is:

$$(1 - g)\, X_{(j)} + g\, X_{(j+1)}$$

where j is the integer part of np, g is the fractional part, and $X_{(.)}$ are the order statistics.

Using the Table 8 mean destruction efficiencies of individual incinerators within each reference document study, selected lognormal percentile estimates were calculated for Table 10. Metal-specific lognormal estimates of the 10th percentile, 25th percentile, and 50th percentile (median) destruction efficiency were determined as follows:

Let R_{ij} = mean destruction efficiency estimate of metal i for incinerator j;

$n_{i.}$ = total number of incinerators (across reference document studies) with mean destruction efficiency estimates for metal i;

$\ln R_{ij}$ = natural logarithm of R_{ij};

$$\hat{\mu} = \sum_{j=1}^{n_{i.}} (\ln R_{ij})/n_{i.}$$

$$\hat{\sigma}^2 = \sum_{j=1}^{n_{i.}} (\ln R_{ij} - \hat{\mu})^2/(n_{i.} - 1)$$

Using the estimates of $\hat{\mu}$ and $\hat{\sigma}^2$ defined above, the lognormal based estimates of the 10th percentile (P_{10}), 25th percentile (P_{25}), and median (P_{50}) were calculated as follows:

$$\hat{P}_{10} = \exp(\hat{\mu} - 1.282\,\hat{\sigma})$$

$$\hat{P}_{25} = \exp(\hat{\mu} - 0.675\,\hat{\sigma})$$

$$\hat{P}_{50} = \exp(\hat{\mu})$$

For example, the following aluminum-specific mean destruction efficiency estimates of individual incinerators within reference studies were extracted from Table 8.

Reference Study	Incinerator Id	R_{ij} Mean Destruction(*)
R4	10	100 (1)
R5	13	99.99 (1)
	14	99.85 (1)
	15	99.99 (1)
	16	100 (1)
R8	20	95.48 (2)
R9	20	99.26 (3)

(*) = Following the destruction efficiency in parenthesis is the number of individual removals on which the mean destruction R_{ij} is based.

Therefore, $n_{i.}$ = 7 (the number of mean incinerator destruction estimates for aluminum across the 4 reference studies)

$$\hat{\mu} = \sum_{j=1}^{7} \ln R_{ij}/7 = 4.597258467$$

$$\hat{\sigma}^2 = \sum_{j=1}^{7} (\ln R_{ij} - \hat{\mu})^2/6 = 0.000293101$$

$$\hat{\sigma} = 0.017120183.$$

Using these estimates, lognormal percentile estimates were obtained as follows:

$$\hat{P}_{10} = \exp(\hat{\mu} - 1.282\ \hat{\sigma}) = 97.06$$

$$\hat{P}_{25} = \exp(\hat{\mu} - 0.675\ \hat{\sigma}) = 98.07$$

$$\hat{P}_{50} = \exp(\hat{\mu}) = 99.21.$$

The above lognormal percentile estimates correspond to those presented in Table 10 for aluminum.

Observe that in Table 10, the statistics for mercury show negative removal efficiencies. This is due to a single negative removal efficiency of -298.5% from Reference 10.

Appendix A-1 presents lognormal probability plots of the mean destruction efficiencies that were used to produce the statistics presented in Table 10. Appendix A-2 presents lognormal probability plots of the metal-specific mean emission rates corresponding to the mean destruction efficiencies of Appendix A-1.

Table 8

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES
BY INCINERATOR WITHIN REFERENCE DOCUMENT

--- REFERENCE =R1 ---

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	1	6	88.44	96.74	98.28	99.49	4.34	.	.
CADMIUM	1	6	59.58	89.48	96.17	99.99	16.16	.	.
CHROMIUM	1	6	99.34	99.86	99.91	100.00	0.26	.	.
COPPER	1	6	98.92	99.69	99.79	99.96	0.40	.	.
LEAD	1	6	92.16	97.27	99.44	100.00	3.90	.	.
NICKEL	1	6	100.00	100.00	100.00	100.00	0.00	.	.
ZINC	1	6	99.66	99.92	99.96	100.00	0.13	.	.

--- REFERENCE =R3 ---

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	11	1	100.00	100.00	100.00	100.00	.	.	.
CADMIUM	10	6	94.42	97.90	97.65	99.97	2.03	.	.
CADMIUM	11	1	99.60	99.60	99.60	99.60	.	.	.
CADMIUM	12	3	99.97	99.97	99.97	99.98	0.00	.	.
CHROMIUM	10	6	98.82	99.58	99.76	99.96	0.45	.	.
CHROMIUM	11	1	98.44	98.44	98.44	98.44	.	.	.
CHROMIUM	12	3	99.79	99.84	99.83	99.87	0.04	.	.
COPPER	10	6	99.84	99.91	99.89	99.99	0.06	.	.
COPPER	11	1	99.99	99.99	99.99	99.99	.	.	.
COPPER	12	3	99.75	99.80	99.78	99.84	0.05	.	.
LEAD	10	6	98.20	99.32	99.12	99.96	0.67	.	.
LEAD	11	1	99.19	99.19	99.19	99.19	.	.	.
LEAD	12	3	96.96	97.73	97.15	98.91	1.04	.	.
MERCURY	11	1	79.84	79.84	79.84	79.84	.	.	.
SILVER	10	6	100.00	100.00	100.00	100.00	0.00	.	.
SILVER	11	1	99.82	99.82	99.82	99.82	.	.	.
ZINC	10	6	99.89	99.95	99.93	100.00	0.05	.	.
ZINC	11	1	99.48	99.48	99.48	99.48	.	.	.
ZINC	12	3	98.53	99.09	98.75	99.77	0.63	.	.

--- REFERENCE =R4 ---

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ALUMINUM	10	1	100.00	100.00	100.00	100.00	.	.	.
ANTIMONY	10	1	99.95	99.95	99.95	99.95	.	.	.
BARIUM	10	1	99.93	99.93	99.93	99.93	.	.	.
BROMINE	10	1	99.90	99.90	99.90	99.90	.	.	.
CADMIUM	10	1	99.90	99.90	99.90	99.90	.	.	.
CAESIUM	10	1	99.98	99.98	99.98	99.98	.	.	.
CALCIUM	10	1	99.99	99.99	99.99	99.99	.	.	.
CERIUM	10	1	99.98	99.98	99.98	99.98	.	.	.
CHLORINE	10	1	99.98	99.98	99.98	99.98	.	.	.
CHROMIUM	10	1	99.99	99.99	99.99	99.99	.	.	.
COBALT	10	1	99.99	99.99	99.99	99.99	.	.	.
COPPER	10	1	99.99	99.99	99.99	99.99	.	.	.

Table 8 (continued)
DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES BY INCINERATOR WITHIN REFERENCE DOCUMENT

-- REFERENCE =R4 --

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
EUROPIUM	10	1	99.99	99.99	99.99	99.99	.	.	.
IRON	10	1	99.99	99.99	99.99	99.99	.	.	.
LEAD	10	1	99.97	99.97	99.97	99.97	.	.	.
MAGNESIUM	10	1	99.99	99.99	99.99	99.99	.	.	.
MANGANESE	10	1	100.00	100.00	100.00	100.00	.	.	.
SCANDIUM	10	1	100.00	100.00	100.00	100.00	.	.	.
SELENIUM	10	1	99.47	99.47	99.47	99.47	.	.	.
SILVER	10	1	99.96	99.96	99.96	99.96	.	.	.
SODIUM	10	1	99.92	99.92	99.92	99.92	.	.	.
TANTALUM	10	1	100.00	100.00	100.00	100.00	.	.	.
TITANIUM	10	1	99.99	99.99	99.99	99.99	.	.	.
VANADIUM	10	1	99.98	99.98	99.98	99.98	.	.	.
YTTERBIUM	10	1	99.90	99.90	99.90	99.90	.	.	.
ZINC	10	1	99.99	99.99	99.99	99.99	.	.	.

-- REFERENCE =R5 --

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ALUMINUM	13	1	99.99	99.99	99.99	99.99	.	.	.
ALUMINUM	14	1	99.85	99.85	99.85	99.85	.	.	.
ALUMINUM	15	1	99.99	99.99	99.99	99.99	.	.	.
ALUMINUM	16	1	100.00	100.00	100.00	100.00	.	.	.
ANTIMONY	13	1	99.92	99.92	99.92	99.92	.	.	.
ANTIMONY	14	1	99.57	99.57	99.57	99.57	.	.	.
ANTIMONY	15	1	100.00	100.00	100.00	100.00	.	.	.
ANTIMONY	16	1	99.32	99.32	99.32	99.32	.	.	.
BARIUM	13	1	99.99	99.99	99.99	99.99	.	.	.
BARIUM	14	1	99.77	99.77	99.77	99.77	.	.	.
BARIUM	15	1	99.99	99.99	99.99	99.99	.	.	.
BARIUM	16	1	99.99	99.99	99.99	99.99	.	.	.
CADMIUM	13	1	99.24	99.24	99.24	99.24	.	.	.
CADMIUM	14	1	99.70	99.70	99.70	99.70	.	.	.
CADMIUM	15	1	99.98	99.98	99.98	99.98	.	.	.
CADMIUM	16	1	89.59	89.59	89.59	89.59	.	.	.
CALCIUM	13	1	99.98	99.98	99.98	99.98	.	.	.
CALCIUM	14	1	99.86	99.86	99.86	99.86	.	.	.
CALCIUM	15	1	99.99	99.99	99.99	99.99	.	.	.
CALCIUM	16	1	100.00	100.00	100.00	100.00	.	.	.
CHLORINE	13	1	99.82	99.82	99.82	99.82	.	.	.
CHLORINE	14	1	99.44	99.44	99.44	99.44	.	.	.
CHLORINE	16	1	99.52	99.52	99.52	99.52	.	.	.
CHROMIUM	13	1	99.84	99.84	99.84	99.84	.	.	.
CHROMIUM	14	1	99.68	99.68	99.68	99.68	.	.	.
CHROMIUM	15	1	99.99	99.99	99.99	99.99	.	.	.
CHROMIUM	16	1	99.90	99.90	99.90	99.90	.	.	.
COBALT	13	1	100.00	100.00	100.00	100.00	.	.	.
COBALT	14	1	99.71	99.71	99.71	99.71	.	.	.
COBALT	15	1	100.00	100.00	100.00	100.00	.	.	.
COBALT	16	1	100.00	100.00	100.00	100.00	.	.	.

Table 8 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES
BY INCINERATOR WITHIN REFERENCE DOCUMENT

-- REFERENCE =R5 --

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
COPPER	13	1	100.00	100.00	100.00	100.00	.	.	.
COPPER	14	1	99.64	99.64	99.64	99.64	.	.	.
COPPER	15	1	99.99	99.99	99.99	99.99	.	.	.
COPPER	16	1	99.80	99.80	99.80	99.80	.	.	.
IRON	13	1	99.98	99.98	99.98	99.98	.	.	.
IRON	14	1	99.86	99.86	99.86	99.86	.	.	.
IRON	15	1	99.99	99.99	99.99	99.99	.	.	.
IRON	16	1	99.99	99.99	99.99	99.99	.	.	.
LEAD	13	1	99.45	99.45	99.45	99.45	.	.	.
LEAD	14	1	99.19	99.19	99.19	99.19	.	.	.
LEAD	15	1	99.96	99.96	99.96	99.96	.	.	.
LEAD	16	1	98.46	98.46	98.46	98.46	.	.	.
MAGNESIUM	13	1	99.98	99.98	99.98	99.98	.	.	.
MAGNESIUM	14	1	99.85	99.85	99.85	99.85	.	.	.
MAGNESIUM	15	1	99.99	99.99	99.99	99.99	.	.	.
MAGNESIUM	16	1	100.00	100.00	100.00	100.00	.	.	.
MANGANESE	13	1	99.99	99.99	99.99	99.99	.	.	.
MANGANESE	14	1	99.88	99.88	99.88	99.88	.	.	.
MANGANESE	15	1	99.98	99.98	99.98	99.98	.	.	.
MANGANESE	16	1	99.99	99.99	99.99	99.99	.	.	.
NICKEL	13	1	100.00	100.00	100.00	100.00	.	.	.
NICKEL	14	1	99.71	99.71	99.71	99.71	.	.	.
NICKEL	15	1	100.00	100.00	100.00	100.00	.	.	.
NICKEL	16	1	100.00	100.00	100.00	100.00	.	.	.
PHOSPHORUS	13	1	99.97	99.97	99.97	99.97	.	.	.
PHOSPHORUS	14	1	99.87	99.87	99.87	99.87	.	.	.
PHOSPHORUS	15	1	99.99	99.99	99.99	99.99	.	.	.
PHOSPHORUS	16	1	99.97	99.97	99.97	99.97	.	.	.
POTASSIUM	13	1	99.94	99.94	99.94	99.94	.	.	.
POTASSIUM	14	1	99.86	99.86	99.86	99.86	.	.	.
POTASSIUM	15	1	99.99	99.99	99.99	99.99	.	.	.
POTASSIUM	16	1	99.98	99.98	99.98	99.98	.	.	.
SILICON	13	1	99.98	99.98	99.98	99.98	.	.	.
SILICON	14	1	99.89	99.89	99.89	99.89	.	.	.
SILICON	15	1	100.00	100.00	100.00	100.00	.	.	.
SILICON	16	1	99.99	99.99	99.99	99.99	.	.	.
SODIUM	13	1	99.87	99.87	99.87	99.87	.	.	.
SODIUM	14	1	99.86	99.86	99.86	99.86	.	.	.
SULFUR	13	1	99.74	99.74	99.74	99.74	.	.	.
SULFUR	14	1	99.76	99.76	99.76	99.76	.	.	.
SULFUR	15	1	99.80	99.80	99.80	99.80	.	.	.
SULFUR	16	1	99.08	99.08	99.08	99.08	.	.	.
TIN	13	1	99.78	99.78	99.78	99.78	.	.	.
TIN	14	1	98.36	98.36	98.36	98.36	.	.	.
TIN	15	1	99.97	99.97	99.97	99.97	.	.	.
TIN	16	1	99.31	99.31	99.31	99.31	.	.	.
TITANIUM	13	1	99.99	99.99	99.99	99.99	.	.	.
TITANIUM	14	1	99.80	99.80	99.80	99.80	.	.	.
TITANIUM	15	1	99.99	99.99	99.99	99.99	.	.	.
TITANIUM	16	1	100.00	100.00	100.00	100.00	.	.	.
VANADIUM	13	1	99.57	99.57	99.57	99.57	.	.	.
VANADIUM	14	1	99.70	99.70	99.70	99.70	.	.	.

Table 8 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES BY INCINERATOR WITHIN REFERENCE DOCUMENT

REFERENCE =R5

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
VANADIUM	15	1	99.93	99.93	99.93	99.93	.	.	.
ZINC	13	1	99.02	99.02	99.02	99.02	.	.	.
ZINC	14	1	99.44	99.44	99.44	99.44	.	.	.
ZINC	15	1	99.98	99.98	99.98	99.98	.	.	.
ZINC	16	1	99.78	99.78	99.78	99.78	.	.	.

REFERENCE =R7

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CADMIUM	19	3	99.90	99.97	99.95	100.00	0.05	.	.
CHROMIUM	19	3	98.91	99.28	99.15	99.54	0.33	.	.
COPPER	19	3	99.90	99.95	99.93	99.98	0.04	.	.
LEAD	19	3	99.73	99.80	99.74	99.93	0.11	.	.
MERCURY	19	1	2.50	2.50	2.50	2.50	.	.	.
NICKEL	19	3	99.74	99.83	99.75	100.00	0.15	.	.
ZINC	19	3	100.00	100.00	100.00	100.00	0.00	.	.

REFERENCE =R8

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ALUMINUM	20	2	91.94	95.48	91.94	99.01	5.00	.	.
ANTIMONY	20	2	99.88	99.90	99.88	99.91	0.02	.	.
ARSENIC	20	2	99.95	99.97	99.95	99.98	0.02	.	.
BARIUM	20	2	99.19	99.53	99.19	99.88	0.48	.	.
CADMIUM	20	2	96.71	97.55	96.71	98.40	1.20	.	.
CALCIUM	20	2	99.98	99.99	99.98	99.99	0.00	.	.
CHROMIUM	20	2	99.43	99.62	99.43	99.80	0.27	.	.
COBALT	20	2	100.00	100.00	100.00	100.00	0.00	.	.
COPPER	20	2	99.94	99.95	99.94	99.96	0.02	.	.
GOLD	20	2	100.00	100.00	100.00	100.00	0.00	.	.
IRON	20	2	99.99	99.99	99.99	99.99	0.00	.	.
LEAD	20	2	99.33	99.54	99.33	99.76	0.30	.	.
MAGNESIUM	20	2	99.99	99.99	99.99	100.00	0.01	.	.
MANGANESE	20	2	99.92	99.93	99.92	99.93	0.01	.	.
NICKEL	20	2	98.20	98.67	98.20	99.14	0.67	.	.
PHOSPHORUS	20	2	99.99	100.00	99.99	100.00	0.00	.	.
SELENIUM	20	1	99.96	99.96	99.96	99.96	.	.	.
SILVER	20	1	99.45	99.45	99.45	99.45	.	.	.
SODIUM	20	2	99.42	99.55	99.42	99.68	0.18	.	.
SULFUR	20	2	99.53	99.59	99.53	99.65	0.09	.	.
TIN	20	2	99.49	99.66	99.49	99.83	0.24	.	.
TITANIUM	20	2	100.00	100.00	100.00	100.00	0.00	.	.
VANADIUM	20	2	99.71	99.79	99.71	99.87	0.12	.	.
ZINC	20	2	99.90	99.92	99.90	99.94	0.03	.	.

Table 8 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES BY INCINERATOR WITHIN REFERENCE DOCUMENT

--- REFERENCE =R9 ---

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ALUMINUM	20	3	98.60	99.26	99.05	99.69	0.58	.	.
ANTIMONY	20	3	99.57	99.79	99.73	99.91	0.19	.	.
ARSENIC	20	3	99.84	99.88	99.87	99.92	0.04	.	.
BARIUM	20	3	99.52	99.73	99.68	99.83	0.18	.	.
CADMIUM	20	3	94.82	96.59	95.97	97.82	1.57	.	.
CALCIUM	20	3	98.57	99.34	99.14	99.75	0.67	.	.
CHROMIUM	20	3	96.60	98.65	97.97	100.00	1.80	.	.
COBALT	20	3	99.75	99.89	99.85	99.98	0.12	.	.
COPPER	20	3	99.66	99.80	99.75	99.89	0.12	.	.
GOLD	20	1	99.58	99.58	99.58	99.58	.	.	.
IRON	20	3	99.73	99.88	99.82	99.99	0.14	.	.
LEAD	20	3	98.10	98.99	98.62	99.72	0.82	.	.
MAGNESIUM	20	3	99.97	99.97	99.97	99.98	0.00	.	.
MANGANESE	20	3	99.35	99.73	99.59	100.00	0.34	.	.
NICKEL	20	3	95.24	98.39	97.58	100.00	2.72	.	.
PHOSPHORUS	20	3	99.98	99.98	99.98	99.99	0.01	.	.
SODIUM	20	3	99.57	99.78	99.67	100.00	0.21	.	.
SULFUR	20	3	98.42	99.00	98.68	99.66	0.62	.	.
TIN	20	3	96.68	97.95	97.25	99.36	1.35	.	.
TITANIUM	20	3	99.88	99.94	99.91	99.98	0.05	.	.
VANADIUM	20	3	99.47	99.77	99.69	99.92	0.26	.	.
ZINC	20	3	99.71	99.81	99.75	99.94	0.12	.	.

--- REFERENCE =R10 ---

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CADMIUM	21	7	32.64	53.55	47.30	74.45	17.95	.	.
LEAD	21	7	28.43	67.44	68.55	91.30	23.12	.	.
MERCURY	21	7	-614.00	-298.51	-369.00	56.45	221.32	.	.

--- REFERENCE =R11 ---

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CADMIUM	2	1	87.24	87.24	87.24	87.24	.	.	.
CADMIUM	3	1	81.97	81.97	81.97	81.97	.	.	.
CADMIUM	4	1	75.08	75.08	75.08	75.08	.	.	.
CADMIUM	5	1	96.27	96.27	96.27	96.27	.	.	.
CADMIUM	6	1	96.79	96.79	96.79	96.79	.	.	.
CADMIUM	8	1	99.98	99.98	99.98	99.98	.	.	.
CADMIUM	9	1	40.25	40.25	40.25	40.25	.	.	.
CHROMIUM	2	1	99.89	99.89	99.89	99.89	.	.	.
CHROMIUM	3	1	99.79	99.79	99.79	99.79	.	.	.
CHROMIUM	4	1	99.45	99.45	99.45	99.45	.	.	.
CHROMIUM	5	1	99.98	99.98	99.98	99.98	.	.	.
CHROMIUM	6	1	99.76	99.76	99.76	99.76	.	.	.
CHROMIUM	8	1	99.98	99.98	99.98	99.98	.	.	.

Table 8 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES
BY INCINERATOR WITHIN REFERENCE DOCUMENT

-- REFERENCE =R11 --

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CHROMIUM	9	1	88.92	88.92	88.92	88.92	.	.	.
COPPER	2	1	99.71	99.71	99.71	99.71	.	.	.
COPPER	3	1	99.68	99.68	99.68	99.68	.	.	.
COPPER	4	1	98.68	98.68	98.68	98.68	.	.	.
COPPER	5	1	99.97	99.97	99.97	99.97	.	.	.
COPPER	6	1	99.65	99.65	99.65	99.65	.	.	.
COPPER	8	1	100.00	100.00	100.00	100.00	.	.	.
COPPER	9	1	92.28	92.28	92.28	92.28	.	.	.
IRON	2	1	99.91	99.91	99.91	99.91	.	.	.
IRON	3	1	99.99	99.99	99.99	99.99	.	.	.
IRON	4	1	99.93	99.93	99.93	99.93	.	.	.
IRON	5	1	100.00	100.00	100.00	100.00	.	.	.
IRON	6	1	99.98	99.98	99.98	99.98	.	.	.
IRON	8	1	99.99	99.99	99.99	99.99	.	.	.
IRON	9	1	98.32	98.32	98.32	98.32	.	.	.
LEAD	2	1	98.28	98.28	98.28	98.28	.	.	.
LEAD	3	1	98.20	98.20	98.20	98.20	.	.	.
LEAD	4	1	80.96	80.96	80.96	80.96	.	.	.
LEAD	5	1	97.43	97.43	97.43	97.43	.	.	.
LEAD	6	1	97.09	97.09	97.09	97.09	.	.	.
LEAD	8	1	99.93	99.93	99.93	99.93	.	.	.
LEAD	9	1	34.22	34.22	34.22	34.22	.	.	.
MANGANESE	2	1	99.93	99.93	99.93	99.93	.	.	.
MANGANESE	3	1	99.97	99.97	99.97	99.97	.	.	.
MANGANESE	4	1	99.07	99.07	99.07	99.07	.	.	.
MANGANESE	5	1	100.00	100.00	100.00	100.00	.	.	.
MANGANESE	6	1	99.97	99.97	99.97	99.97	.	.	.
MANGANESE	8	1	100.00	100.00	100.00	100.00	.	.	.
MANGANESE	9	1	99.40	99.40	99.40	99.40	.	.	.
NICKEL	2	1	99.83	99.83	99.83	99.83	.	.	.
NICKEL	3	1	99.93	99.93	99.93	99.93	.	.	.
NICKEL	4	1	99.43	99.43	99.43	99.43	.	.	.
NICKEL	5	1	99.99	99.99	99.99	99.99	.	.	.
NICKEL	6	1	99.93	99.93	99.93	99.93	.	.	.
NICKEL	8	1	99.97	99.97	99.97	99.97	.	.	.
NICKEL	9	1	93.49	93.49	93.49	93.49	.	.	.
SILVER	2	1	98.50	98.50	98.50	98.50	.	.	.
SILVER	3	1	99.30	99.30	99.30	99.30	.	.	.
SILVER	4	1	98.13	98.13	98.13	98.13	.	.	.
SILVER	5	1	99.75	99.75	99.75	99.75	.	.	.
SILVER	6	1	98.55	98.55	98.55	98.55	.	.	.
SILVER	8	1	99.99	99.99	99.99	99.99	.	.	.
SILVER	9	1	71.44	71.44	71.44	71.44	.	.	.
ZINC	2	1	99.68	99.68	99.68	99.68	.	.	.
ZINC	3	1	99.19	99.19	99.19	99.19	.	.	.
ZINC	4	1	93.42	93.42	93.42	93.42	.	.	.
ZINC	5	1	99.81	99.81	99.81	99.81	.	.	.
ZINC	6	1	99.67	99.67	99.67	99.67	.	.	.
ZINC	8	1	99.99	99.99	99.99	99.99	.	.	.
ZINC	9	1	87.58	87.58	87.58	87.58	.	.	.

Table 8 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES
BY INCINERATOR WITHIN REFERENCE DOCUMENT

REFERENCE =R12

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CHROMIUM	24	4	100.00	100.00	100.00	100.00	0.00	.	.

REFERENCE =R13

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
BERYLLIUM	25	3	100.00	100.00	100.00	100.00	0.00	.	.
CADMIUM	25	4	57.50	68.55	60.22	79.84	11.32	.	.
CHROMIUM	25	7	98.83	99.62	99.75	99.87	0.38	.	.
LEAD	25	7	44.58	67.12	69.27	76.72	12.08	.	.
NICKEL	25	7	33.11	89.15	98.12	100.00	24.73	.	.

REFERENCE =R14

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	26	7	87.63	93.90	94.94	96.60	2.94	.	.
BERYLLIUM	26	7	99.84	99.98	100.00	100.00	0.06	.	.
CADMIUM	26	7	76.64	79.79	77.87	85.01	3.44	.	.
CHROMIUM	26	7	97.24	98.87	99.09	99.67	0.96	.	.
LEAD	26	7	93.73	96.22	96.68	97.36	1.26	.	.
NICKEL	26	7	93.85	97.22	97.30	99.72	2.30	.	.

REFERENCE =R15

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	27	3	99.87	99.89	99.89	99.91	0.02	.	.
BERYLLIUM	27	3	100.00	100.00	100.00	100.00	0.00	.	.
CADMIUM	27	3	95.01	95.91	95.47	96.80	0.89	.	.
CHROMIUM	27	3	99.70	99.75	99.70	99.83	0.07	.	.
LEAD	27	3	99.83	99.87	99.84	99.91	0.04	.	.
NICKEL	27	3	99.38	99.51	99.45	99.62	0.12	.	.

Table 8 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES BY INCINERATOR WITHIN REFERENCE DOCUMENT

-- REFERENCE =R16 --

CONTAMINANT	INCINERATOR ID	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	28	11	99.71	99.94	100.00	100.00	0.10	.	99.72
BERYLLIUM	28	11	100.00	100.00	100.00	100.00	0.00	.	100.00
CADMIUM	28	11	73.79	80.18	79.04	84.83	3.38	.	74.08
COPPER	28	11	98.75	99.23	99.16	99.58	0.26	.	98.77
LEAD	28	11	75.70	88.05	89.39	94.51	6.54	.	76.11
NICKEL	28	11	99.79	99.88	99.88	99.95	0.06	.	99.79
SELENIUM	28	11	100.00	100.00	100.00	100.00	0.00	.	100.00
ZINC	28	11	89.94	93.23	92.37	96.93	2.73	.	89.95

Table 9

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES WITHIN REFERENCE DOCUMENT

--- REFERENCE =R1 ---

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	1	96.74	96.74	96.74	96.74	.	.	.
CADMIUM	1	89.48	89.48	89.48	89.48	.	.	.
CHROMIUM	1	99.86	99.86	99.86	99.86	.	.	.
COPPER	1	99.69	99.69	99.69	99.69	.	.	.
LEAD	1	97.27	97.27	97.27	97.27	.	.	.
NICKEL	1	100.00	100.00	100.00	100.00	.	.	.
ZINC	1	99.92	99.92	99.92	99.92	.	.	.

--- REFERENCE =R3 ---

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	1	100.00	100.00	100.00	100.00	.		
CADMIUM	3	97.90	99.16	98.75	99.97	1.10	.	.
CHROMIUM	3	98.44	99.29	99.01	99.84	0.75	.	.
COPPER	3	99.80	99.90	99.85	99.99	0.10	.	.
LEAD	3	97.73	98.75	98.46	99.32	0.88	.	.
MERCURY	1	79.84	79.84	79.84	79.84	.	.	.
SILVER	2	99.82	99.91	99.82	100.00	0.13	.	.
ZINC	3	99.09	99.51	99.29	99.95	0.43	.	.

--- REFERENCE =R4 ---

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ALUMINUM	1	100.00	100.00	100.00	100.00	.	.	.
ANTIMONY	1	99.95	99.95	99.95	99.95	.	.	.
BARIUM	1	99.93	99.93	99.93	99.93	.	.	.
BROMINE	1	99.90	99.90	99.90	99.90	.	.	.
CADMIUM	1	99.90	99.90	99.90	99.90	.	.	.
CAESIUM	1	99.98	99.98	99.98	99.98	.	.	.
CALCIUM	1	99.99	99.99	99.99	99.99	.	.	.
CERIUM	1	99.98	99.98	99.98	99.98	.	.	.
CHLORINE	1	99.98	99.98	99.98	99.98	.	.	.
CHROMIUM	1	99.99	99.99	99.99	99.99	.	.	.
COBALT	1	99.99	99.99	99.99	99.99	.	.	.
COPPER	1	99.99	99.99	99.99	99.99	.	.	.
EUROPIUM	1	99.99	99.99	99.99	99.99	.	.	.
IRON	1	99.99	99.99	99.99	99.99	.	.	.
LEAD	1	99.97	99.97	99.97	99.97	.	.	.
MAGNESIUM	1	99.99	99.99	99.99	99.99	.	.	.
MANGANESE	1	100.00	100.00	100.00	100.00	.	.	.
SCANDIUM	1	100.00	100.00	100.00	100.00	.	.	.
SELENIUM	1	99.47	99.47	99.47	99.47	.	.	.
SILVER	1	99.96	99.96	99.96	99.96	.	.	.
SODIUM	1	99.92	99.92	99.92	99.92	.	.	.
TANTALUM	1	100.00	100.00	100.00	100.00	.	.	.
TITANIUM	1	99.99	99.99	99.99	99.99	.	.	.

Table 9 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES WITHIN REFERENCE DOCUMENT

REFERENCE =R4

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
VANADIUM	1	99.98	99.98	99.98	99.98	.	.	.
YTTERBIUM	1	99.90	99.90	99.90	99.90	.	.	.
ZINC	1	99.99	99.99	99.99	99.99	.	.	.

REFERENCE =R5

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ALUMINUM	4	99.85	99.96	99.99	100.00	0.07	.	.
ANTIMONY	4	99.32	99.70	99.57	100.00	0.32	.	.
BARIUM	4	99.77	99.93	99.99	99.99	0.11	.	.
CADMIUM	4	89.59	97.13	99.24	99.98	5.03	.	.
CALCIUM	4	99.86	99.96	99.98	100.00	0.07	.	.
CHLORINE	3	99.44	99.59	99.48	99.82	0.20	.	.
CHROMIUM	4	99.68	99.85	99.84	99.99	0.13	.	.
COBALT	4	99.71	99.93	100.00	100.00	0.14	.	.
COPPER	4	99.64	99.86	99.80	100.00	0.17	.	.
IRON	4	99.86	99.96	99.98	99.99	0.06	.	.
LEAD	4	98.46	99.26	99.19	99.96	0.62	.	.
MAGNESIUM	4	99.85	99.95	99.98	100.00	0.07	.	.
MANGANESE	4	99.88	99.96	99.98	99.99	0.05	.	.
NICKEL	4	99.71	99.93	100.00	100.00	0.15	.	.
PHOSPHORUS	4	99.87	99.95	99.97	99.99	0.05	.	.
POTASSIUM	4	99.86	99.94	99.94	99.99	0.06	.	.
SILICON	4	99.89	99.96	99.98	100.00	0.05	.	.
SODIUM	2	99.86	99.87	99.86	99.87	0.01	.	.
SULFUR	4	99.08	99.60	99.74	99.80	0.34	.	.
TIN	4	98.36	99.36	99.31	99.97	0.72	.	.
TITANIUM	4	99.80	99.94	99.99	100.00	0.10	.	.
VANADIUM	3	99.57	99.73	99.64	99.93	0.18	.	.
ZINC	4	99.02	99.56	99.44	99.98	0.42	.	.

REFERENCE =R7

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CADMIUM	1	99.97	99.97	99.97	99.97	.	.	.
CHROMIUM	1	99.28	99.28	99.28	99.28	.	.	.
COPPER	1	99.95	99.95	99.95	99.95	.	.	.
LEAD	1	99.80	99.80	99.80	99.80	.	.	.
MERCURY	1	2.50	2.50	2.50	2.50	.	.	.
NICKEL	1	99.83	99.83	99.83	99.83	.	.	.
ZINC	1	100.00	100.00	100.00	100.00	.	.	.

Table 9 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES WITHIN REFERENCE DOCUMENT

-- REFERENCE =R8 --

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ALUMINUM	1	95.48	95.48	95.48	95.48	.	.	.
ANTIMONY	1	99.90	99.90	99.90	99.90	.	.	.
ARSENIC	1	99.97	99.97	99.97	99.97	.	.	.
BARIUM	1	99.53	99.53	99.53	99.53	.	.	.
CADMIUM	1	97.55	97.55	97.55	97.55	.	.	.
CALCIUM	1	99.99	99.99	99.99	99.99	.	.	.
CHROMIUM	1	99.62	99.62	99.62	99.62	.	.	.
COBALT	1	100.00	100.00	100.00	100.00	.	.	.
COPPER	1	99.95	99.95	99.95	99.95	.	.	.
GOLD	1	100.00	100.00	100.00	100.00	.	.	.
IRON	1	99.99	99.99	99.99	99.99	.	.	.
LEAD	1	99.54	99.54	99.54	99.54	.	.	.
MAGNESIUM	1	99.99	99.99	99.99	99.99	.	.	.
MANGANESE	1	99.93	99.93	99.93	99.93	.	.	.
NICKEL	1	98.67	98.67	98.67	98.67	.	.	.
PHOSPHORUS	1	100.00	100.00	100.00	100.00	.	.	.
SELENIUM	1	99.96	99.96	99.96	99.96	.	.	.
SILVER	1	99.45	99.45	99.45	99.45	.	.	.
SODIUM	1	99.55	99.55	99.55	99.55	.	.	.
SULFUR	1	99.59	99.59	99.59	99.59	.	.	.
TIN	1	99.66	99.66	99.66	99.66	.	.	.
TITANIUM	1	100.00	100.00	100.00	100.00	.	.	.
VANADIUM	1	99.79	99.79	99.79	99.79	.	.	.
ZINC	1	99.92	99.92	99.92	99.92	.	.	.

-- REFERENCE =R9 --

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ALUMINUM	1	99.26	99.26	99.26	99.26	.	.	.
ANTIMONY	1	99.79	99.79	99.79	99.79	.	.	.
ARSENIC	1	99.88	99.88	99.88	99.88	.	.	.
BARIUM	1	99.73	99.73	99.73	99.73	.	.	.
CADMIUM	1	96.59	96.59	96.59	96.59	.	.	.
CALCIUM	1	99.34	99.34	99.34	99.34	.	.	.
CHROMIUM	1	98.65	98.65	98.65	98.65	.	.	.
COBALT	1	99.89	99.89	99.89	99.89	.	.	.
COPPER	1	99.80	99.80	99.80	99.80	.	.	.
GOLD	1	99.58	99.58	99.58	99.58	.	.	.
IRON	1	99.88	99.88	99.88	99.88	.	.	.
LEAD	1	98.99	98.99	98.99	98.99	.	.	.
MAGNESIUM	1	99.97	99.97	99.97	99.97	.	.	.
MANGANESE	1	99.73	99.73	99.73	99.73	.	.	.
NICKEL	1	98.39	98.39	98.39	98.39	.	.	.
PHOSPHORUS	1	99.98	99.98	99.98	99.98	.	.	.
SODIUM	1	99.78	99.78	99.78	99.78	.	.	.
SULFUR	1	99.00	99.00	99.00	99.00	.	.	.
TIN	1	97.95	97.95	97.95	97.95	.	.	.
TITANIUM	1	99.94	99.94	99.94	99.94	.	.	.
VANADIUM	1	99.77	99.77	99.77	99.77	.	.	.

Table 9 (continued)
DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES WITHIN REFERENCE DOCUMENT

REFERENCE =R9

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ZINC	1	99.81	99.81	99.81	99.81	.	.	.

REFERENCE =R10

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CADMIUM	1	53.55	53.55	53.55	53.55	.	.	.
LEAD	1	67.44	67.44	67.44	67.44	.	.	.
MERCURY	1	-298.51	-298.51	-298.51	-298.51	.	.	.

REFERENCE =R11

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CADMIUM	7	40.25	82.51	84.61	99.98	20.67	.	.
CHROMIUM	7	88.92	98.25	99.77	99.98	4.12	.	.
COPPER	7	92.28	98.57	99.66	100.00	2.81	.	.
IRON	7	98.32	99.73	99.95	100.00	0.62	.	.
LEAD	7	34.22	86.59	97.26	99.93	23.98	.	.
MANGANESE	7	99.07	99.76	99.95	100.00	0.38	.	.
NICKEL	7	93.49	98.94	99.88	99.99	2.41	.	.
SILVER	7	71.44	95.09	98.52	99.99	10.45	.	.
ZINC	7	87.58	97.05	99.43	99.99	4.79	.	.

REFERENCE =R12

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
CHROMIUM	1	100.00	100.00	100.00	100.00	.	.	.

REFERENCE =R13

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
BERYLLIUM	1	100.00	100.00	100.00	100.00	.	.	.
CADMIUM	1	68.55	68.55	68.55	68.55	.	.	.
CHROMIUM	1	99.62	99.62	99.62	99.62	.	.	.
LEAD	1	67.12	67.12	67.12	67.12	.	.	.
NICKEL	1	89.15	89.15	89.15	89.15	.	.	.

Table 9 (continued)

DESCRIPTIVE STATISTICS ON MEAN INCINERATOR EFFICIENCIES
WITHIN REFERENCE DOCUMENT

------------------------------ REFERENCE =R14 ------------------------------

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	1	93.90	93.90	93.90	93.90	.	.	.
BERYLLIUM	1	99.98	99.98	99.98	99.98	.	.	.
CADMIUM	1	79.79	79.79	79.79	79.79	.	.	.
CHROMIUM	1	98.87	98.87	98.87	98.87	.	.	.
LEAD	1	96.22	96.22	96.22	96.22	.	.	.
NICKEL	1	97.22	97.22	97.22	97.22	.	.	.

------------------------------ REFERENCE =R15 ------------------------------

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	1	99.89	99.89	99.89	99.89	.	.	.
BERYLLIUM	1	100.00	100.00	100.00	100.00	.	.	.
CADMIUM	1	95.91	95.91	95.91	95.91	.	.	.
CHROMIUM	1	99.75	99.75	99.75	99.75	.	.	.
LEAD	1	99.87	99.87	99.87	99.87	.	.	.
NICKEL	1	99.51	99.51	99.51	99.51	.	.	.

------------------------------ REFERENCE =R16 ------------------------------

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT
ARSENIC	1	99.94	99.94	99.94	99.94	.	.	.
BERYLLIUM	1	100.00	100.00	100.00	100.00	.	.	.
CADMIUM	1	80.18	80.18	80.18	80.18	.	.	.
COPPER	1	99.23	99.23	99.23	99.23	.	.	.
LEAD	1	88.05	88.05	88.05	88.05	.	.	.
NICKEL	1	99.88	99.88	99.88	99.88	.	.	.
SELENIUM	1	100.00	100.00	100.00	100.00	.	.	.
ZINC	1	93.23	93.23	93.23	93.23	.	.	.

Table 10

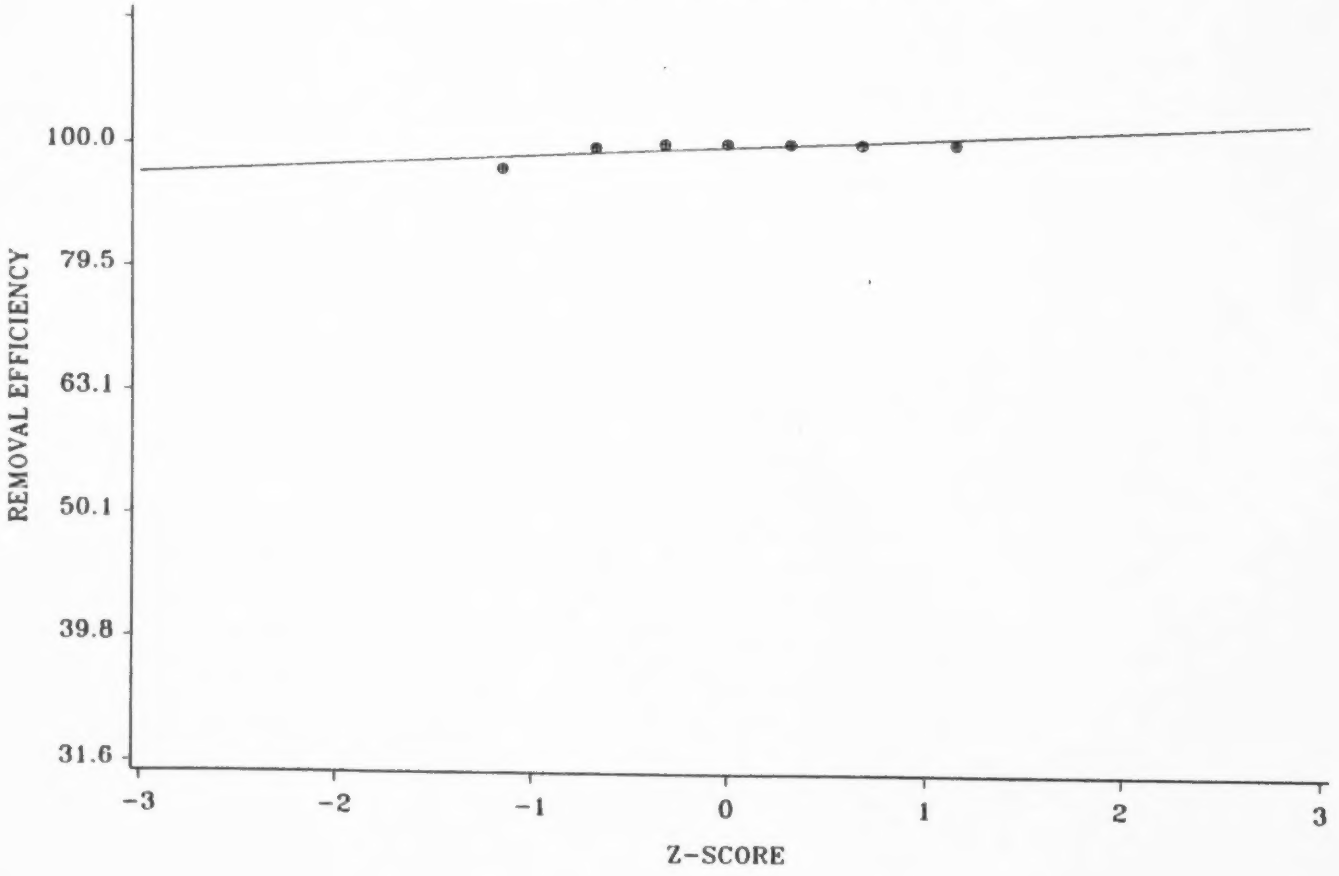
DESCRIPTIVE STATISTICS ON MEAN INCINERATOR REMOVAL EFFICIENCIES ACROSS INCINERATOR AND REFERENCE DOCUMENT

CONTAMINANT	NUMBER OF OBSERVATIONS	MINIMUM	MEAN	MEDIAN	MAXIMUM	STANDARD DEVIATION	NON-PAR 5TH PCT	NON-PAR 10TH PCT	LOGNORMAL 10TH PCT	LOGNORMAL 25TH PCT	LOGNORMAL 50TH PCT
ALUMINUM	7	95.48	99.22	99.92	100.00	1.67	.	.	97.06	98.07	99.21
ANTIMONY	7	99.32	99.78	99.84	100.00	0.25	.	.	99.46	99.61	99.78
ARSENIC	7	93.90	98.62	99.89	100.00	2.40	.	.	95.52	96.96	98.59
BARIUM	7	99.53	99.85	99.85	99.99	0.18	.	.	99.62	99.73	99.85
BERYLLIUM	4	99.98	99.99	100.00	100.00	0.01	.	.	99.98	99.99	99.99
BROMINE	1	99.90	99.90	99.90	99.90	.	.	.	.	.	99.90
CADMIUM	24	40.25	88.54	96.27	99.98	15.83	42.91	59.55	65.15	74.61	86.75
CAESIUM	1	99.98	99.98	99.98	99.98	.	.	.	.	.	99.98
CALCIUM	7	99.34	99.88	99.98	100.00	0.24	.	.	99.57	99.72	99.88
CERIUM	1	99.98	99.98	99.98	99.98	.	.	.	.	.	99.98
CHLORINE	4	99.44	99.69	99.52	99.98	0.25	.	.	99.37	99.52	99.69
CHROMIUM	23	88.92	99.16	99.75	100.00	2.27	90.35	98.50	96.12	97.53	99.13
COBALT	7	99.71	99.94	100.00	100.00	0.11	.	.	99.80	99.87	99.94
COPPER	20	92.28	99.39	99.80	100.00	1.70	92.28	98.68	97.14	98.19	99.37
EUROPIUM	1	99.99	99.99	99.99	99.99	.	.	.	.	.	99.99
GOLD	2	99.58	99.79	99.58	100.00	0.30	.	.	99.41	99.59	99.79
IRON	14	98.32	99.84	99.98	100.00	0.44	.	98.94	99.28	99.54	99.84
LEAD	24	34.22	92.24	98.28	99.97	15.58	40.80	67.25	66.73	77.01	90.31
MAGNESIUM	7	99.85	99.97	99.98	100.00	0.05	.	.	99.90	99.93	99.97
MANGANESE	14	99.07	99.84	99.97	100.00	0.28	.	99.20	99.49	99.66	99.84
MERCURY	3	-298.51	-72.06	-148.00	79.84	199.89	.	.	0.61	2.70	14.13
NICKEL	19	89.15	98.68	99.83	100.00	2.79	.	93.05	95.00	96.71	98.64
PHOSPHORUS	6	99.87	99.96	99.97	100.00	0.05	.	.	99.90	99.93	99.96
POTASSIUM	4	99.86	99.94	99.94	99.99	0.06	.	.	99.87	99.90	99.94
SCANDIUM	1	100.00	100.00	100.00	100.00	.	.	.	.	.	100.00
SELENIUM	3	99.47	99.81	99.72	100.00	0.29	.	.	99.44	99.61	99.81
SILICON	4	99.89	99.96	99.98	100.00	0.05	.	.	99.90	99.93	99.96
SILVER	11	71.44	96.81	99.38	100.00	8.44	.	74.11	84.85	90.14	96.41
SODIUM	5	99.55	99.80	99.82	99.92	0.15	.	.	99.61	99.70	99.80
SULFUR	6	99.00	99.50	99.59	99.80	0.36	.	.	99.04	99.25	99.50
TANTALUM	1	100.00	100.00	100.00	100.00	.	.	.	.	.	100.00
TIN	6	97.95	99.17	99.31	99.97	0.83	.	.	98.12	98.61	99.17
TITANIUM	7	99.80	99.96	99.99	100.00	0.07	.	.	99.87	99.91	99.96
VANADIUM	6	99.57	99.79	99.77	99.98	0.15	.	.	99.60	99.69	99.79
YTTERBIUM	1	99.90	99.90	99.90	99.90	.	.	.	.	.	99.90
ZINC	20	87.58	98.45	99.68	100.00	3.23	87.58	93.23	94.17	96.15	98.40

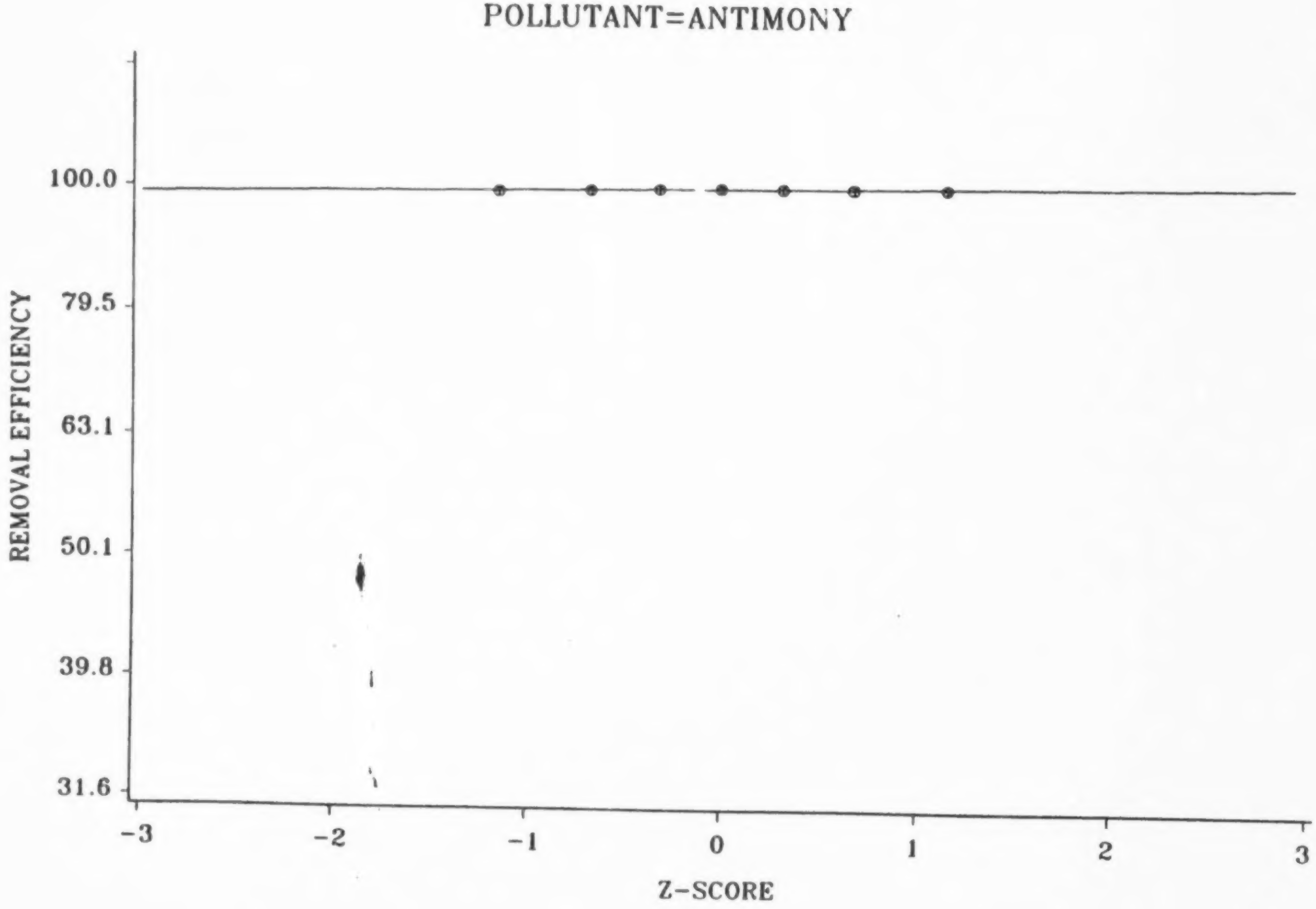
APPENDIX A-1

SAIC

POLLUTANT=ALUMINUM

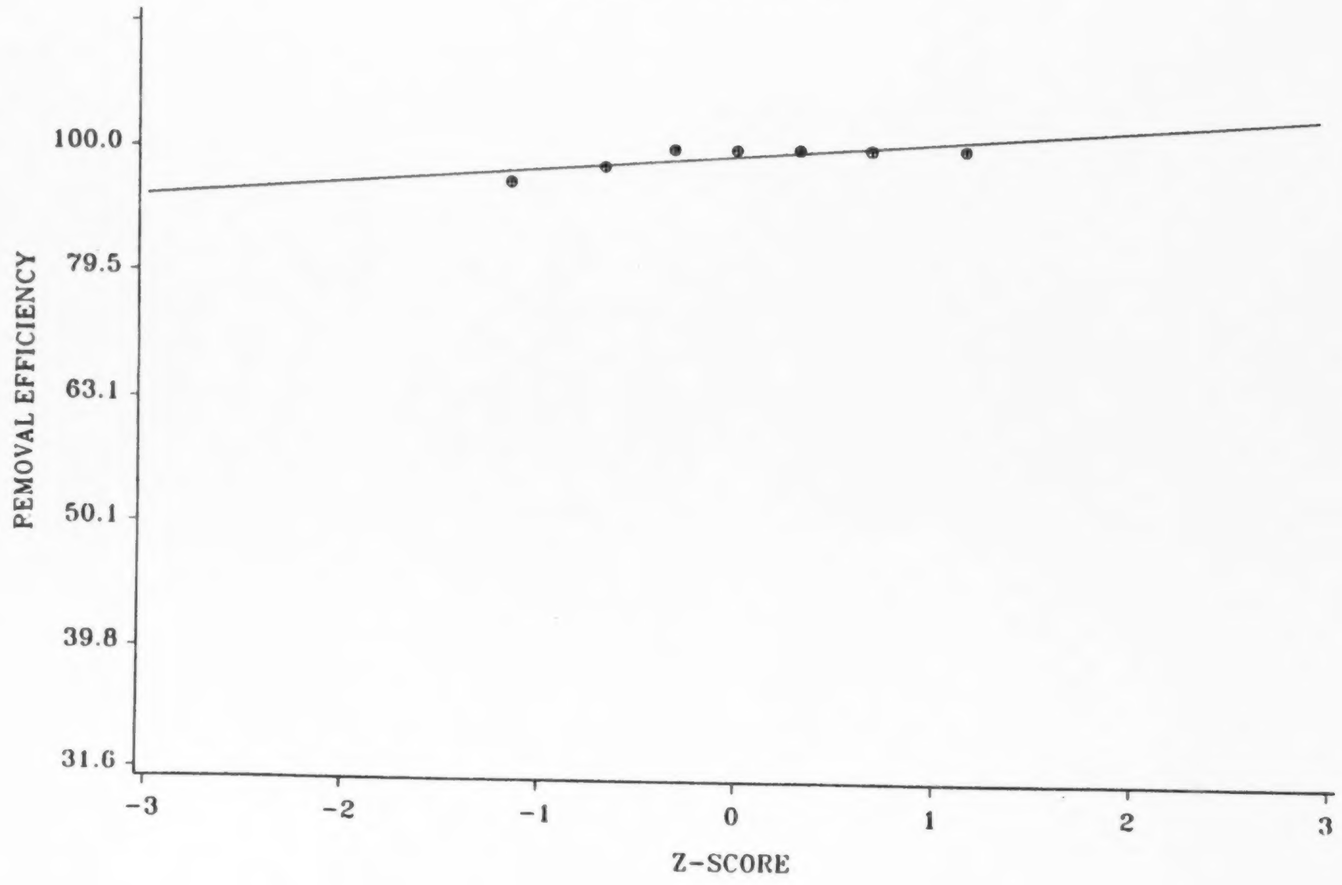


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT



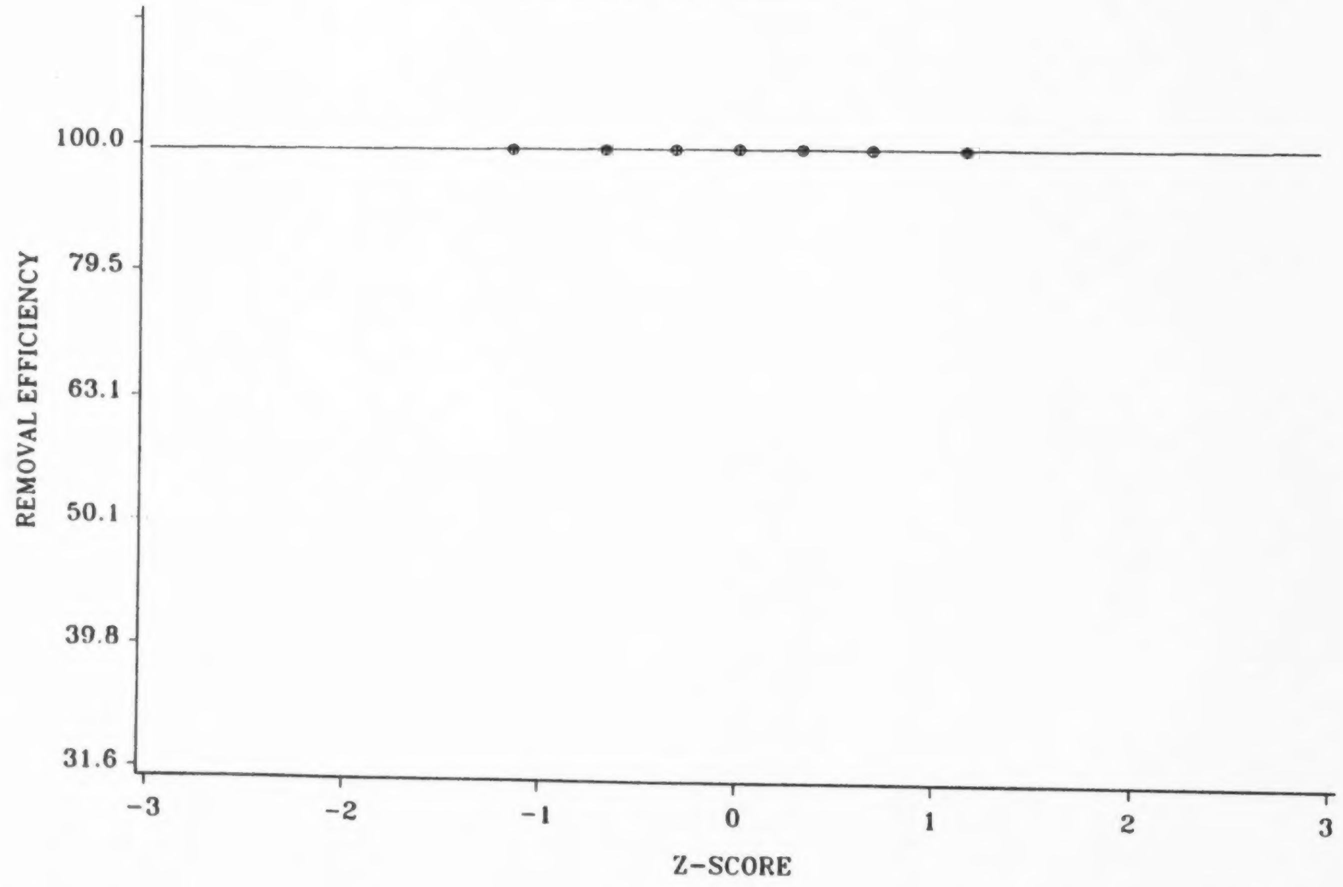
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=ARSENIC



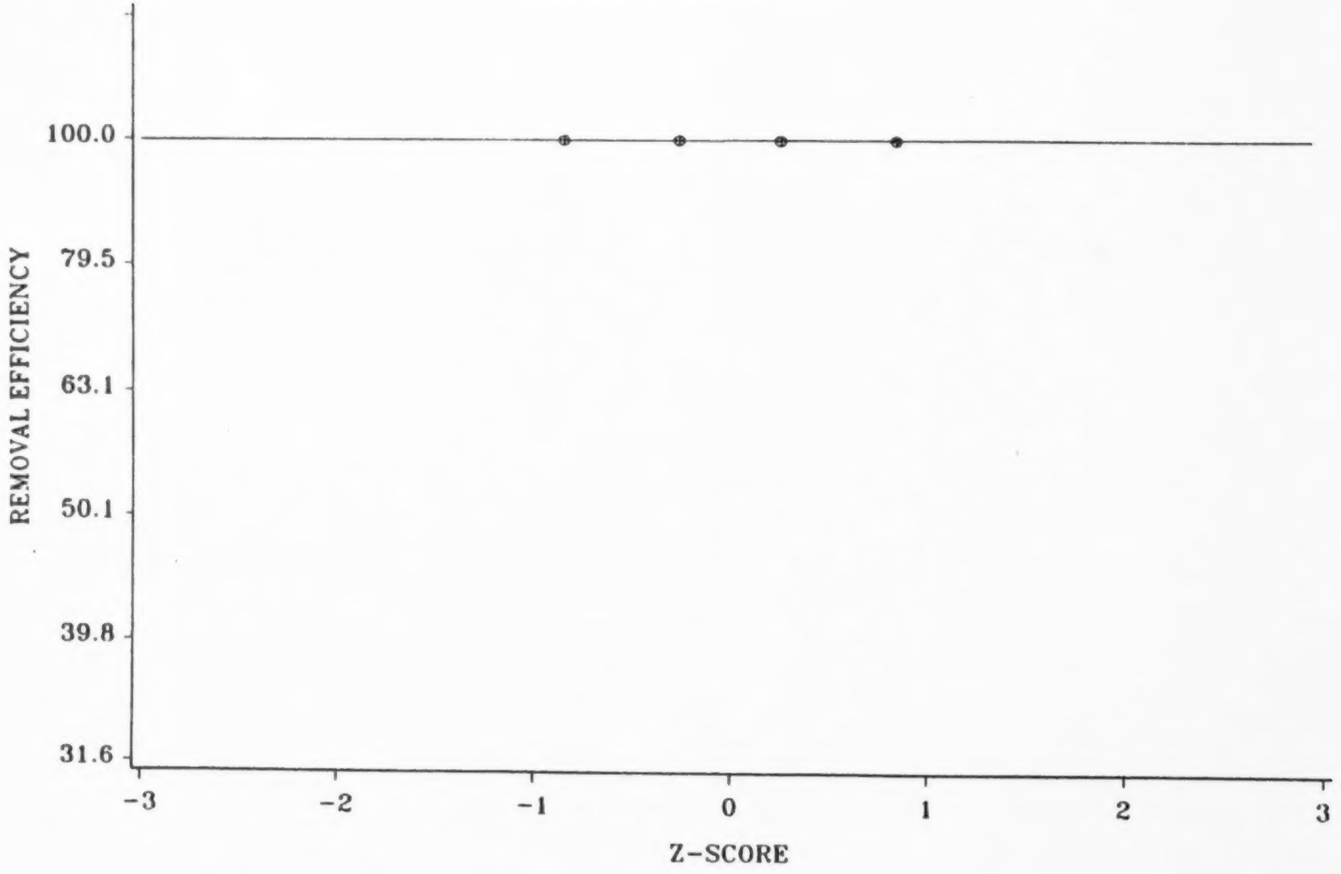
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=BARIUM



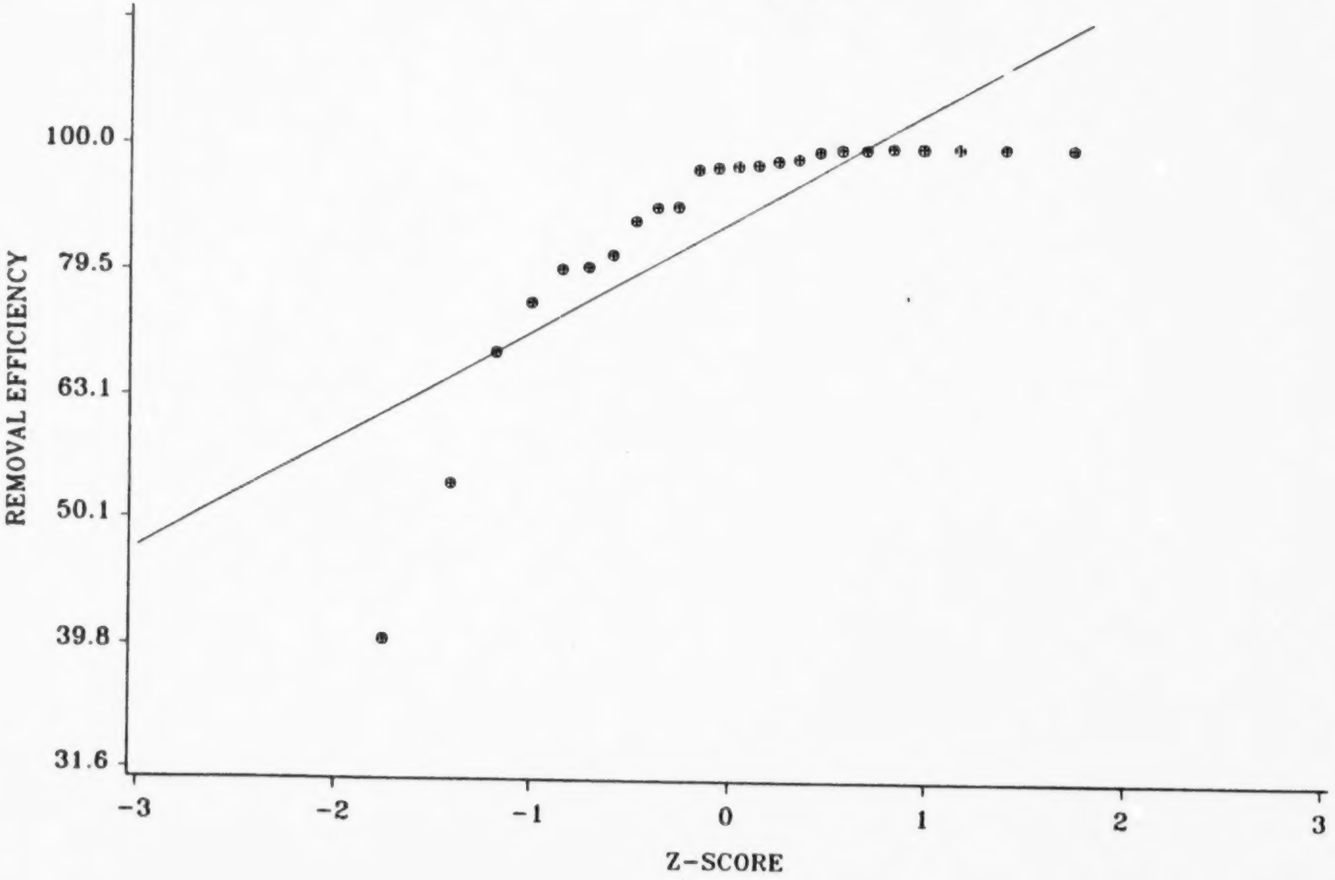
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=BERYLLIUM

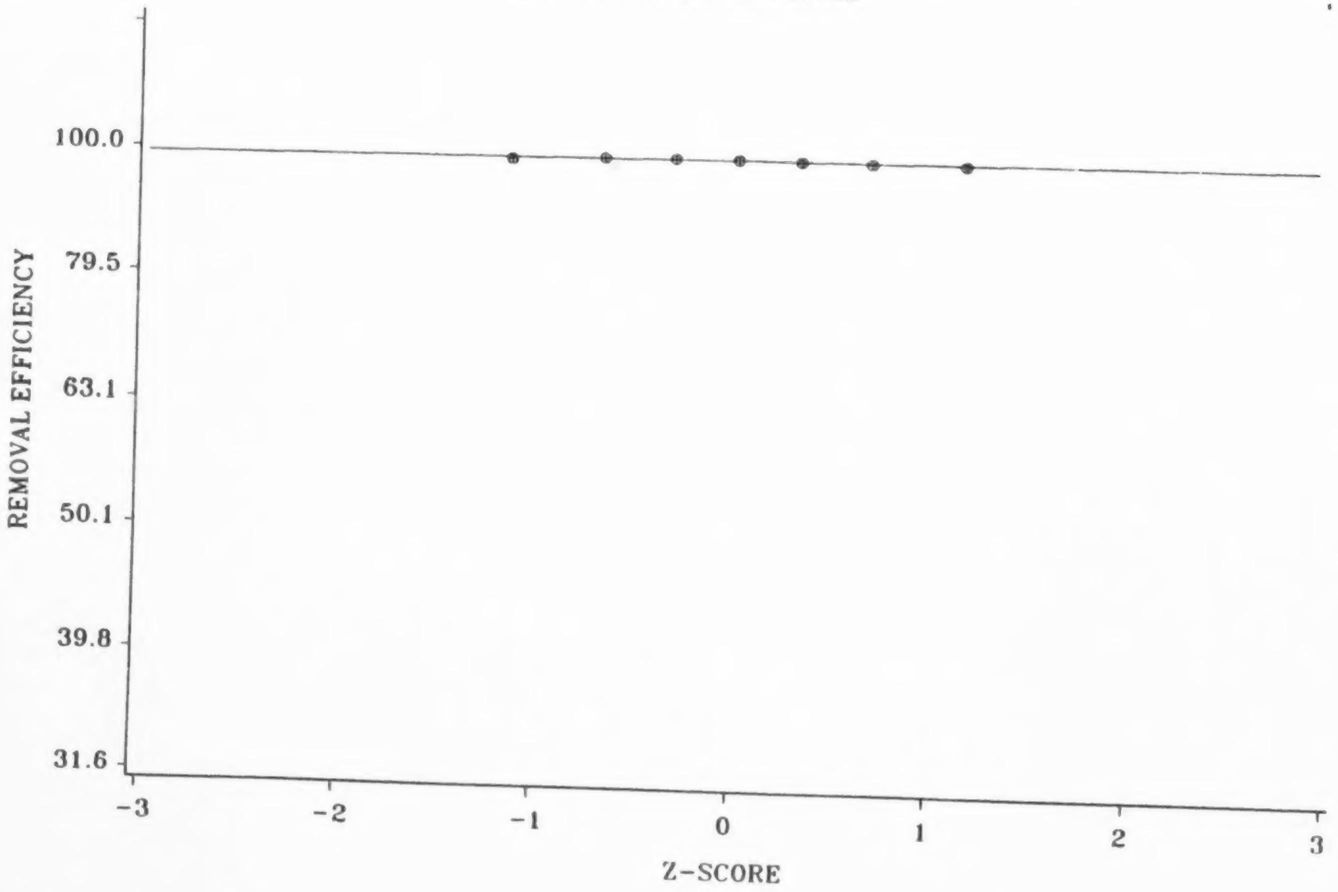


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=CADMIUM

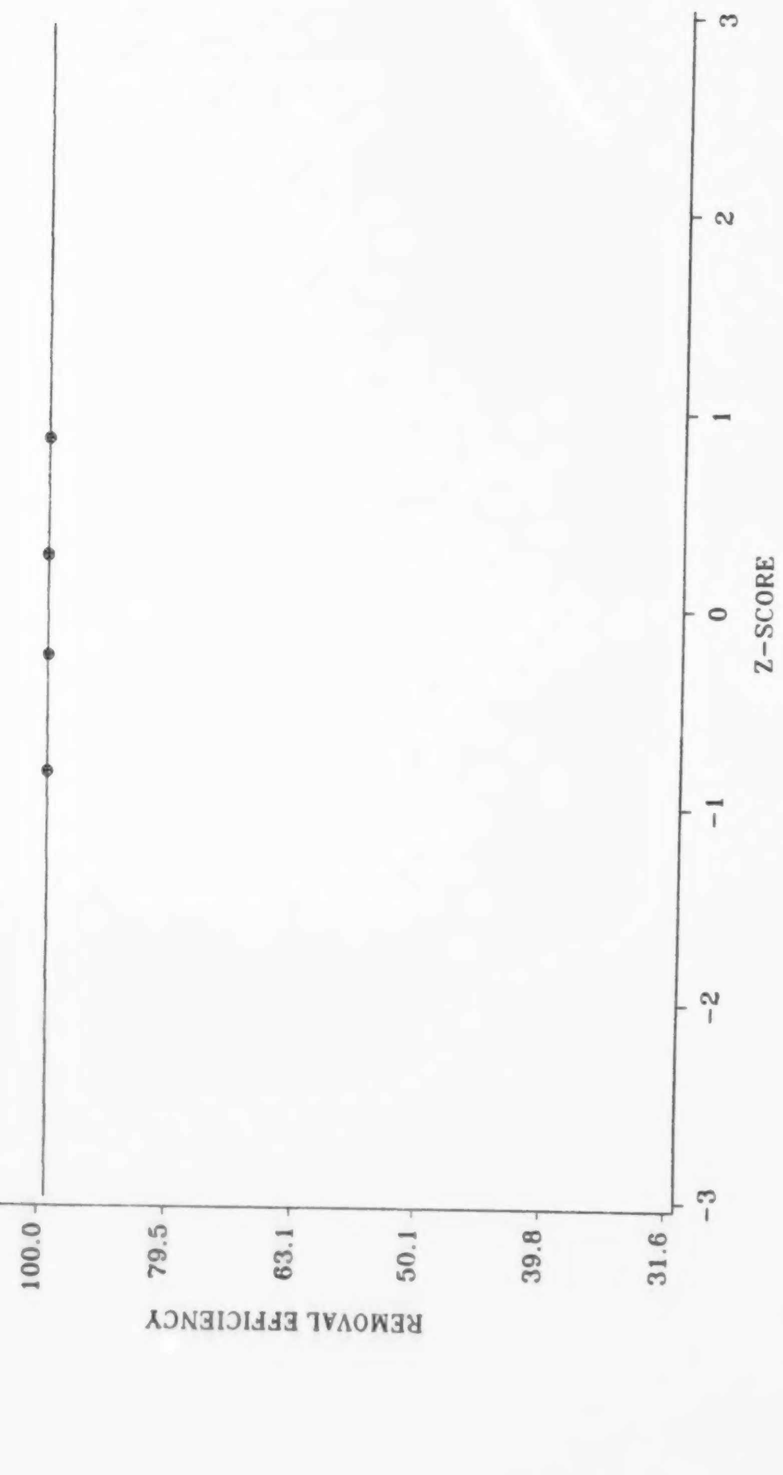


TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT


POLLUTANT=CALCIUM

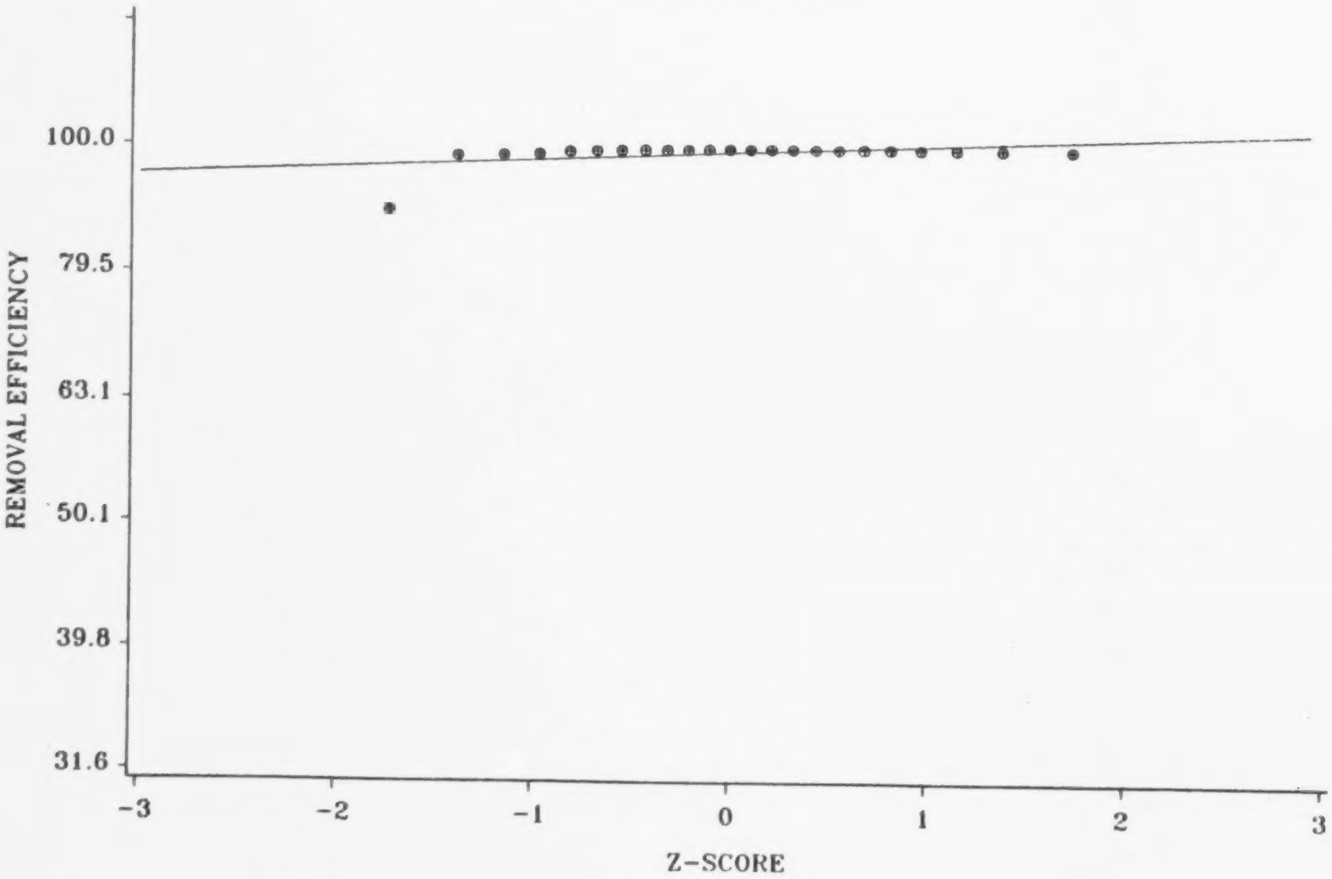
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=CHLORINE



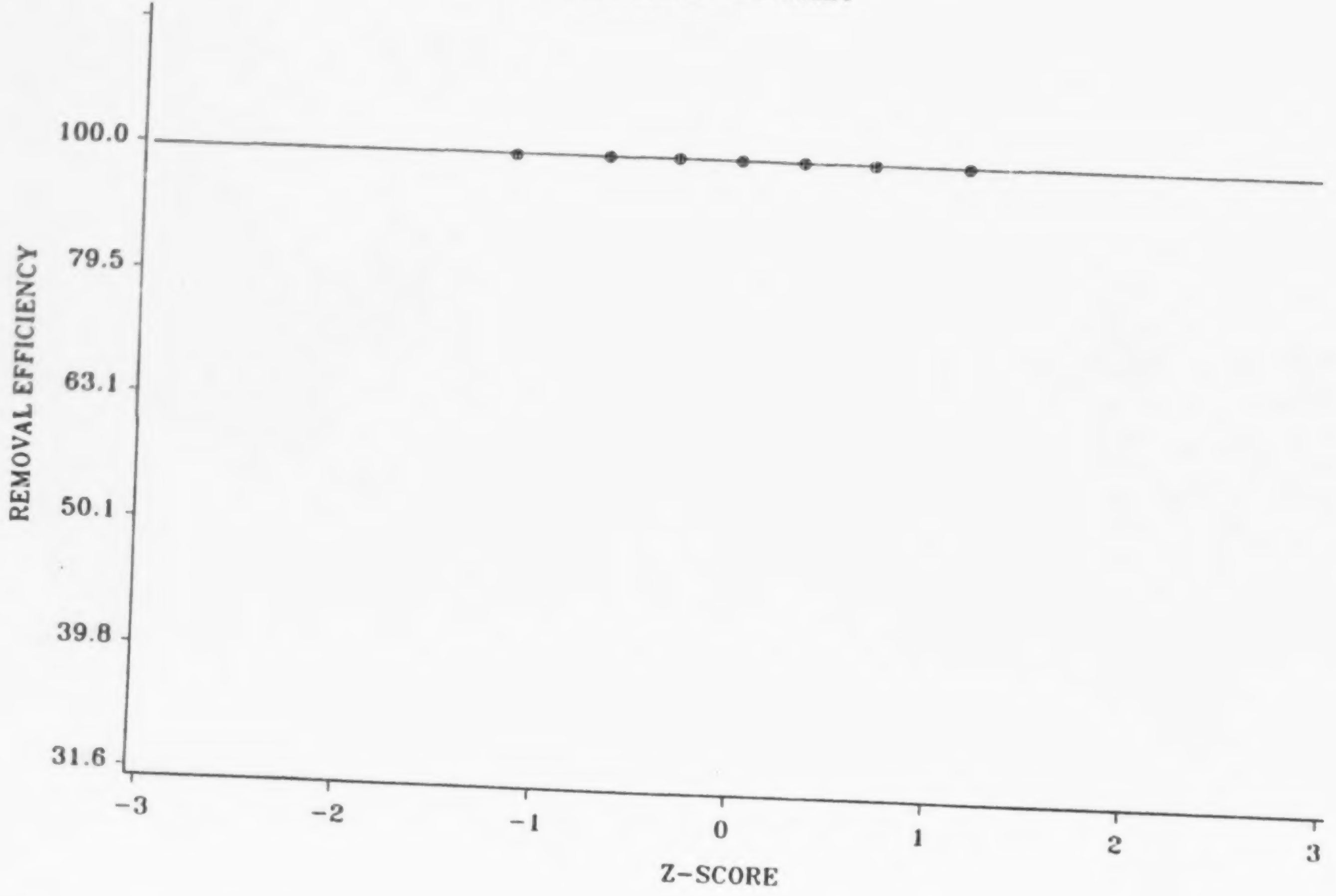
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=CHROMIUM



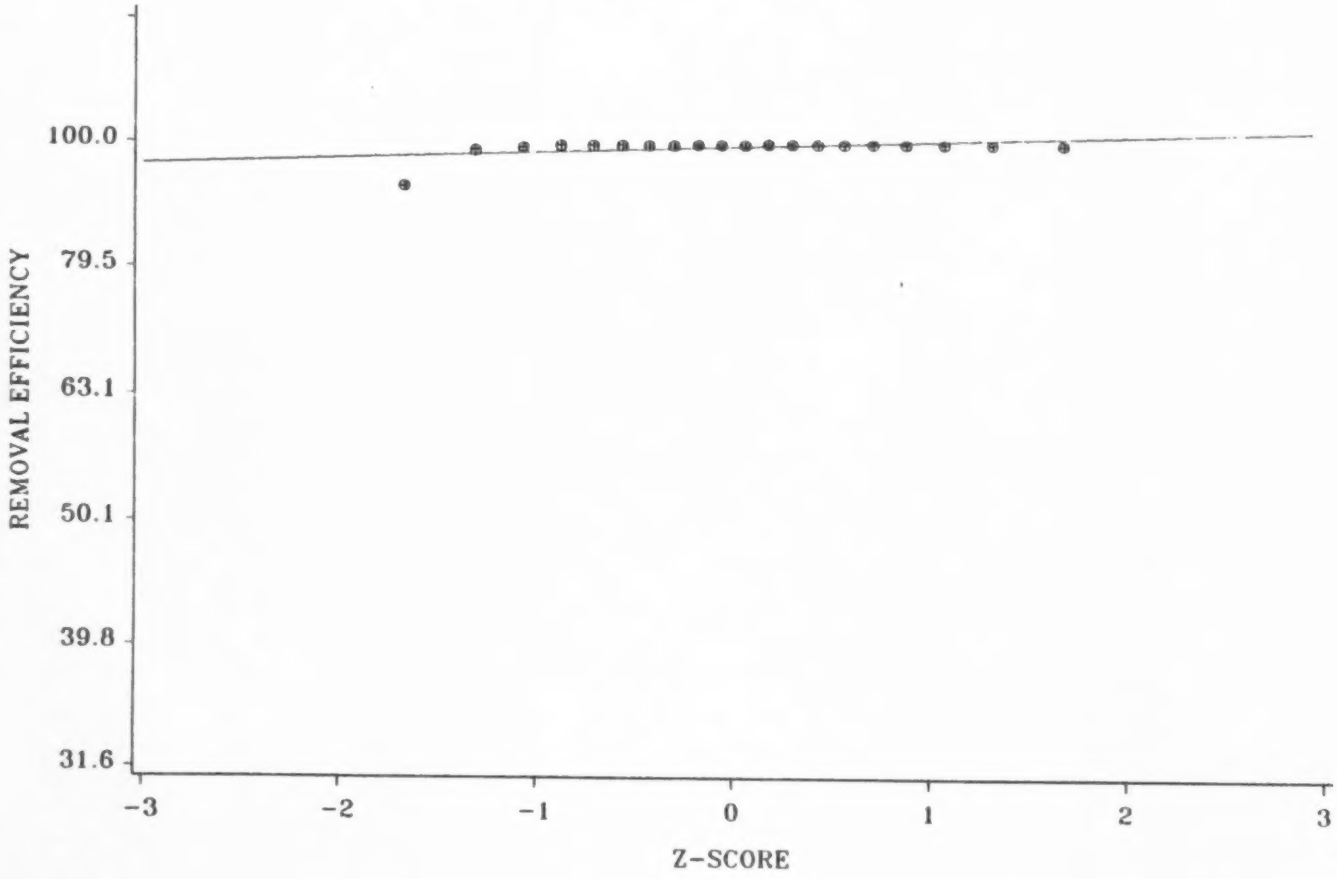
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=COBALT



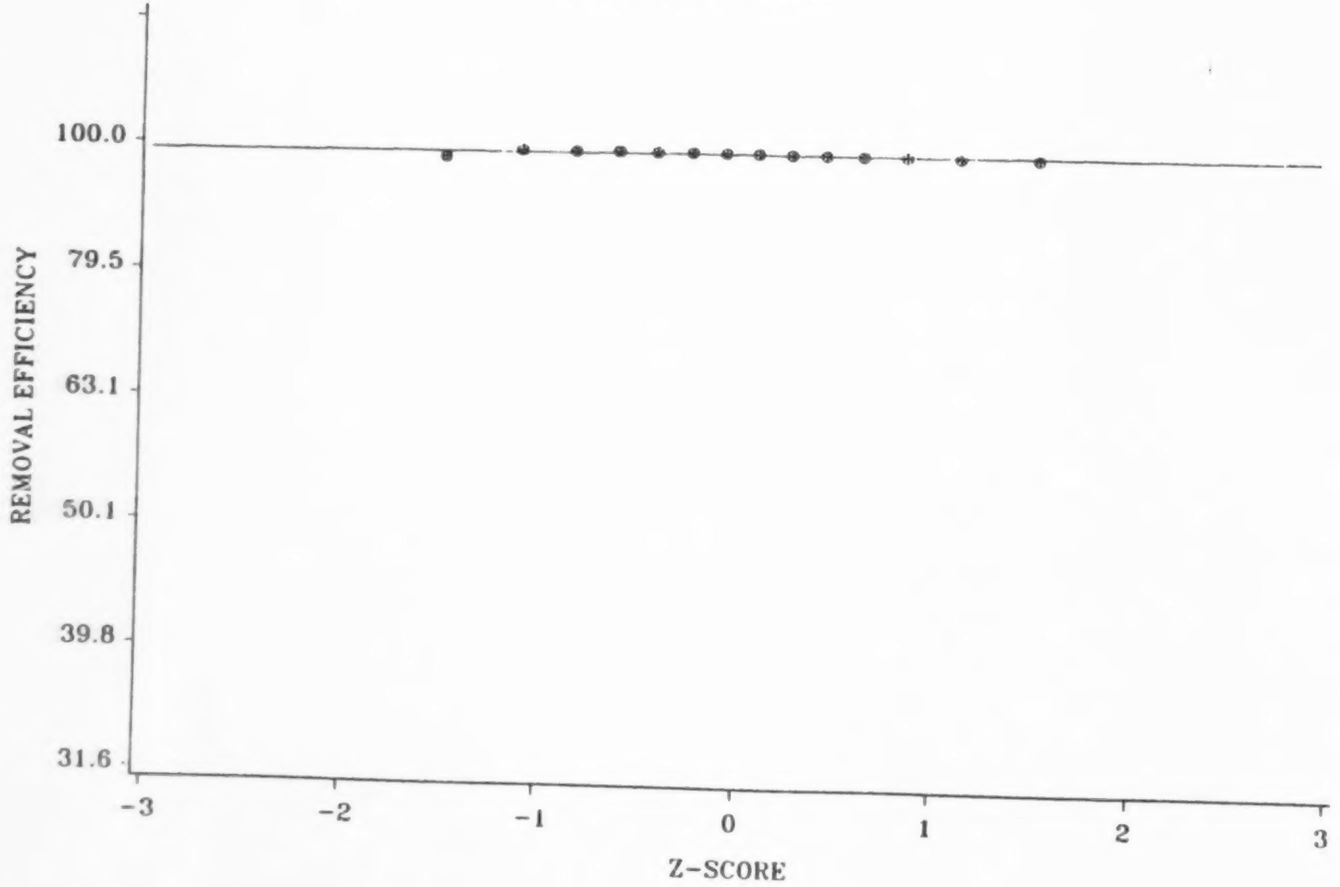
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=COPPER



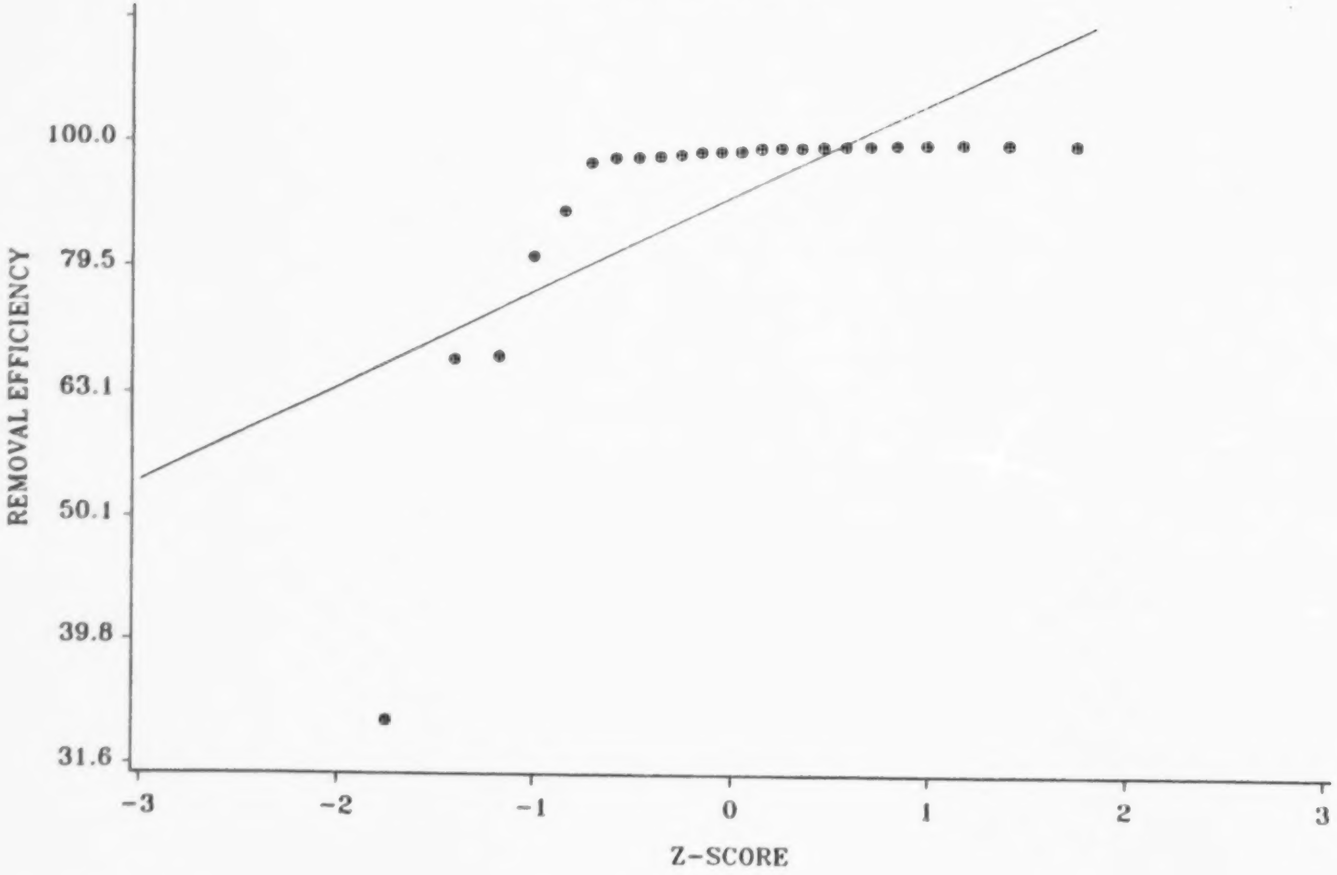
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=IRON



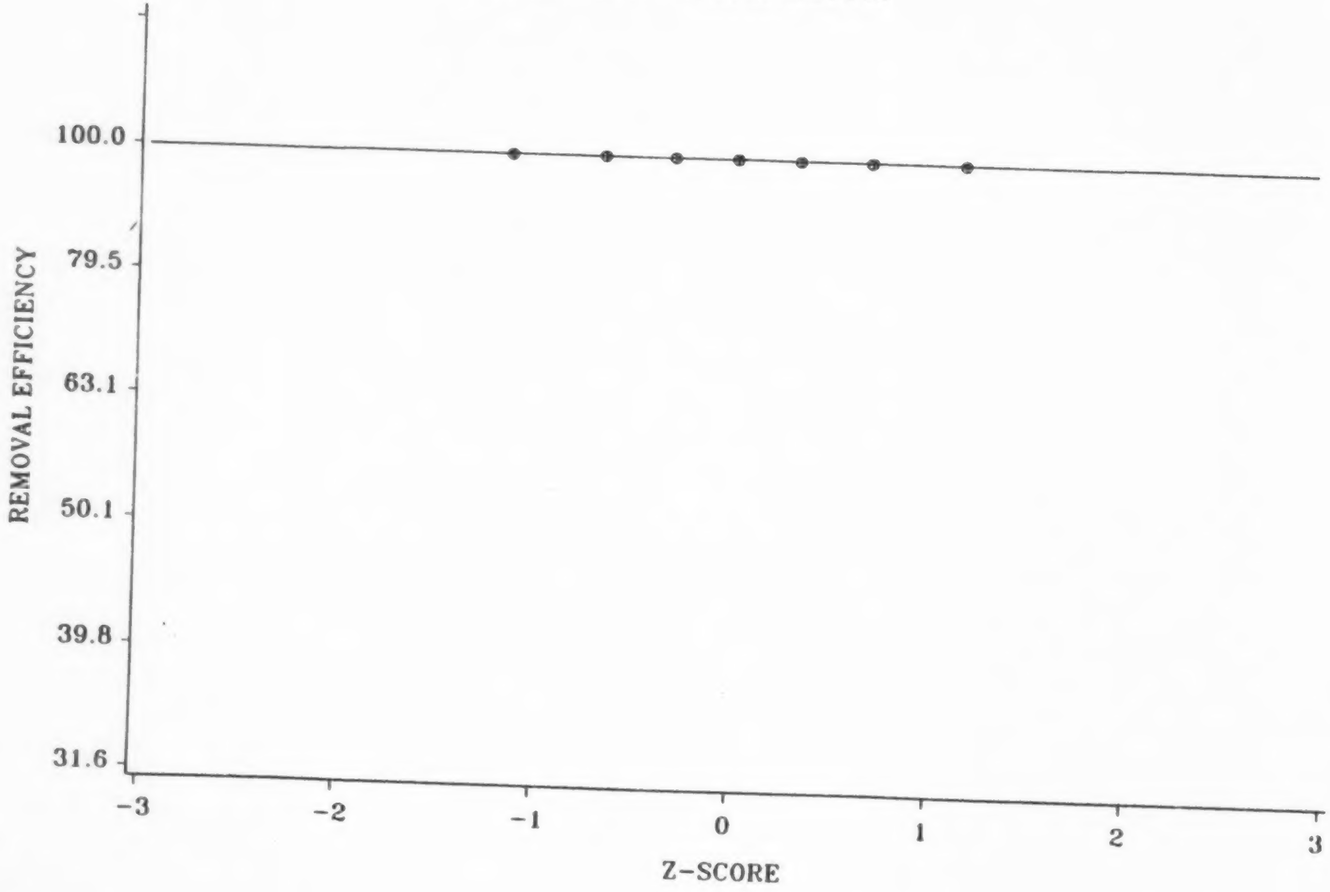
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=LEAD



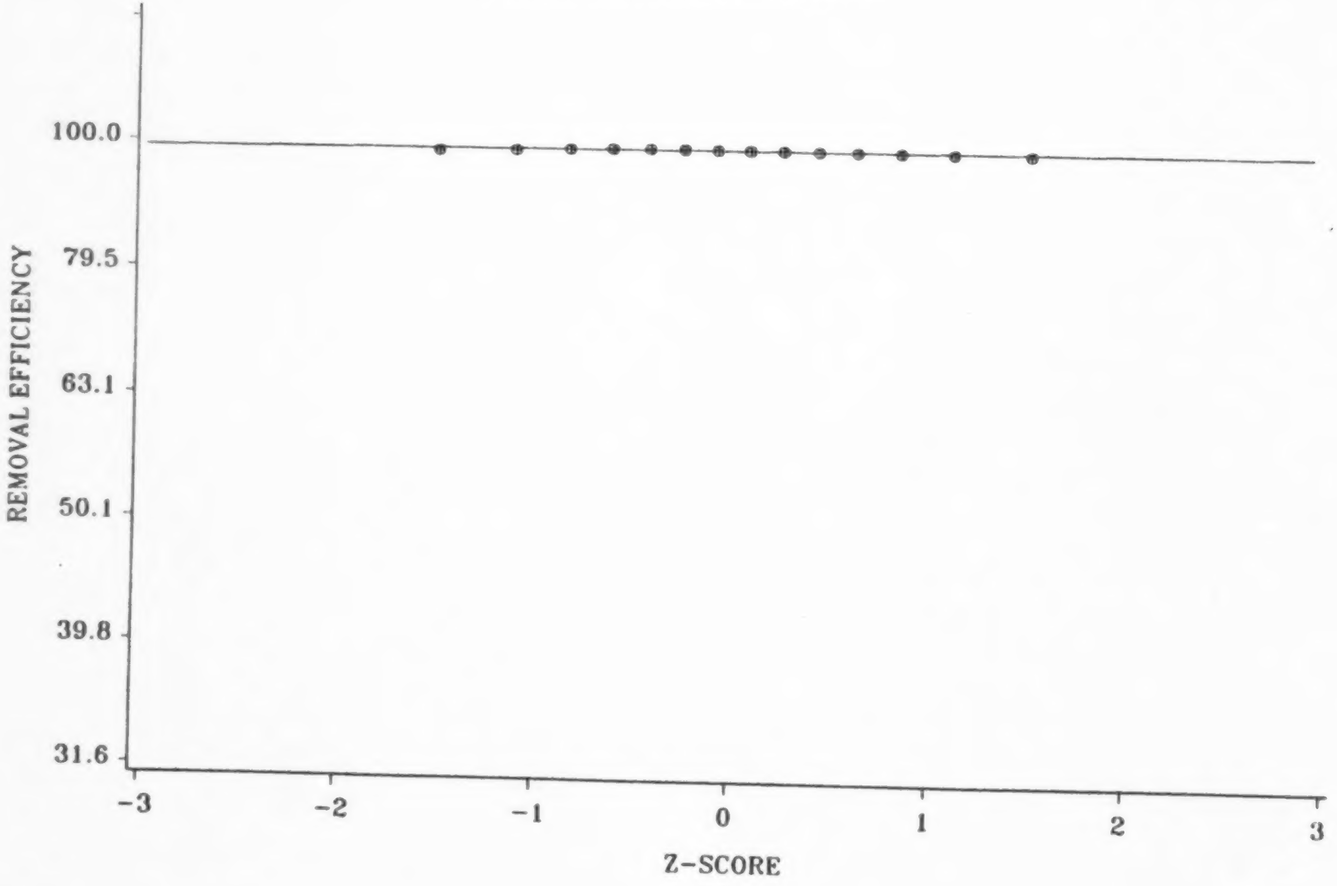
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=MAGNESIUM

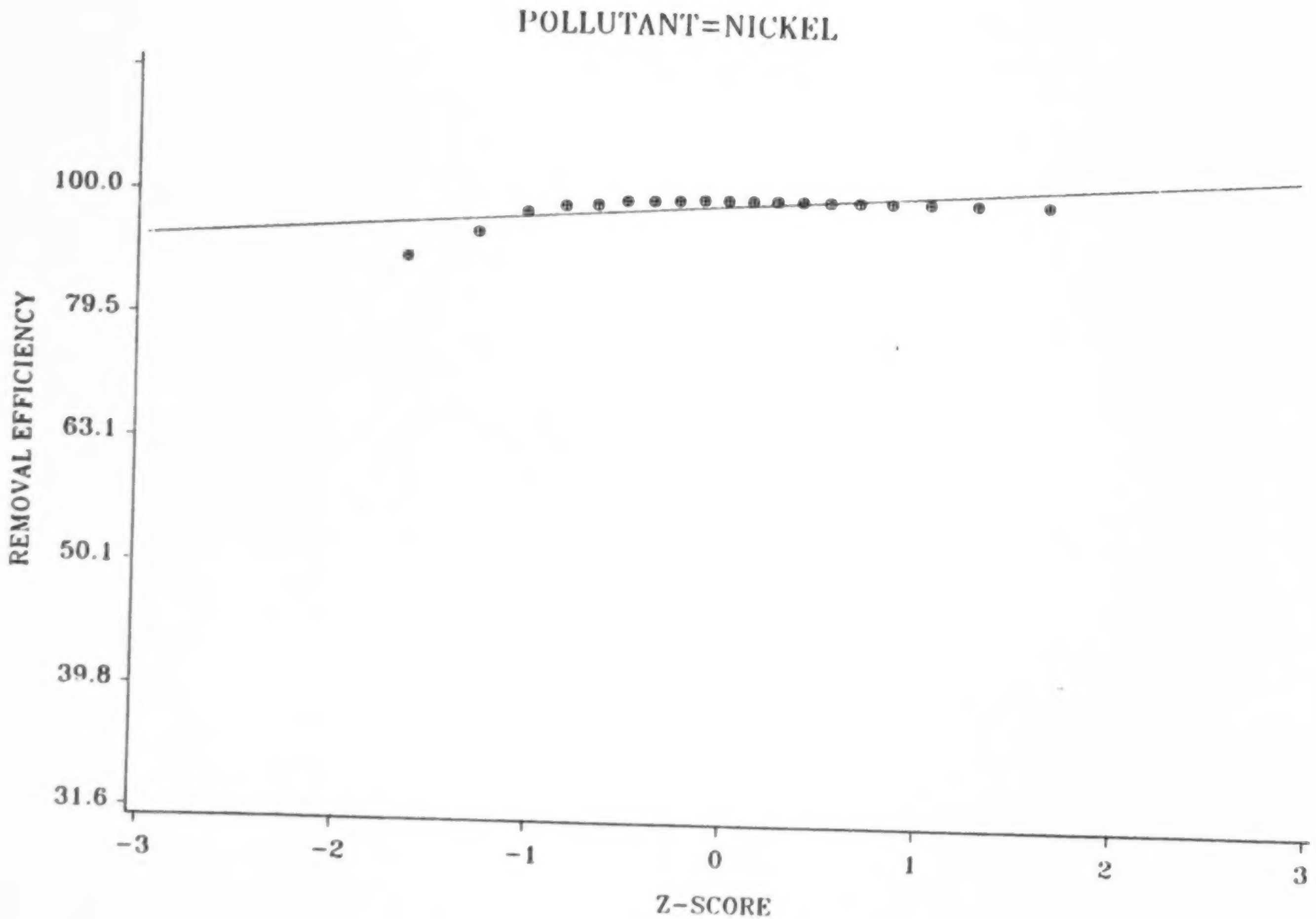


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=MANGANESE

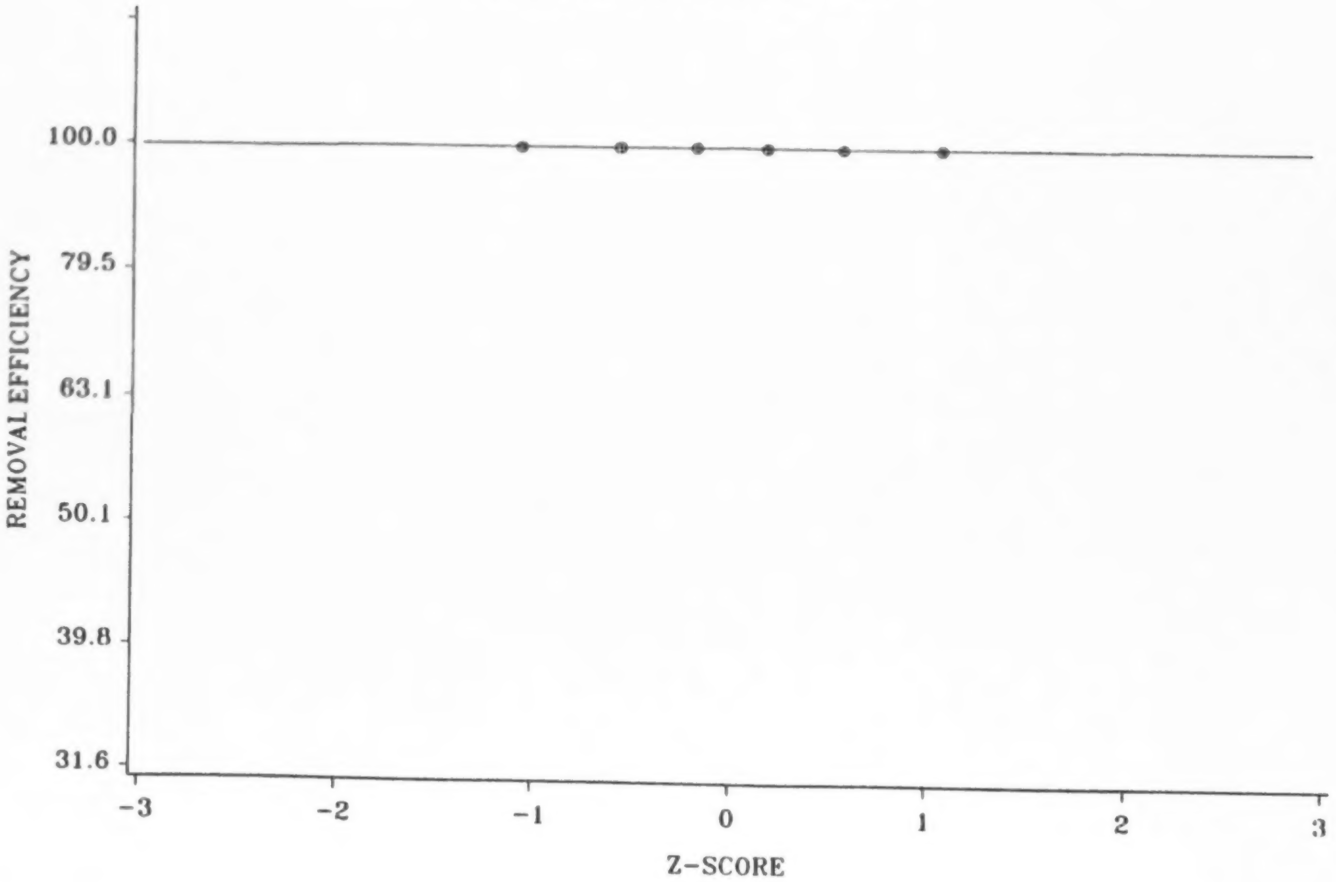


TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

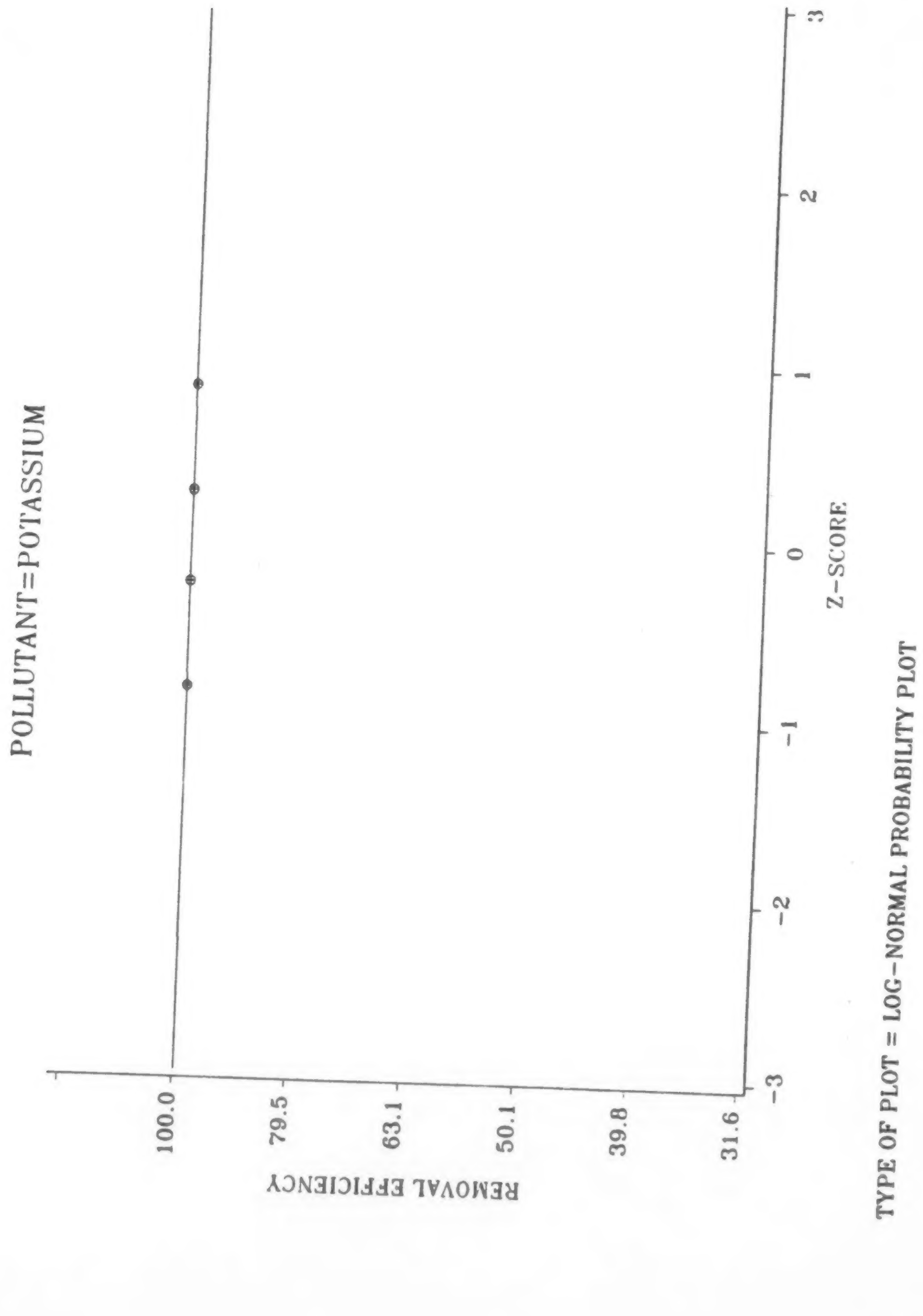


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

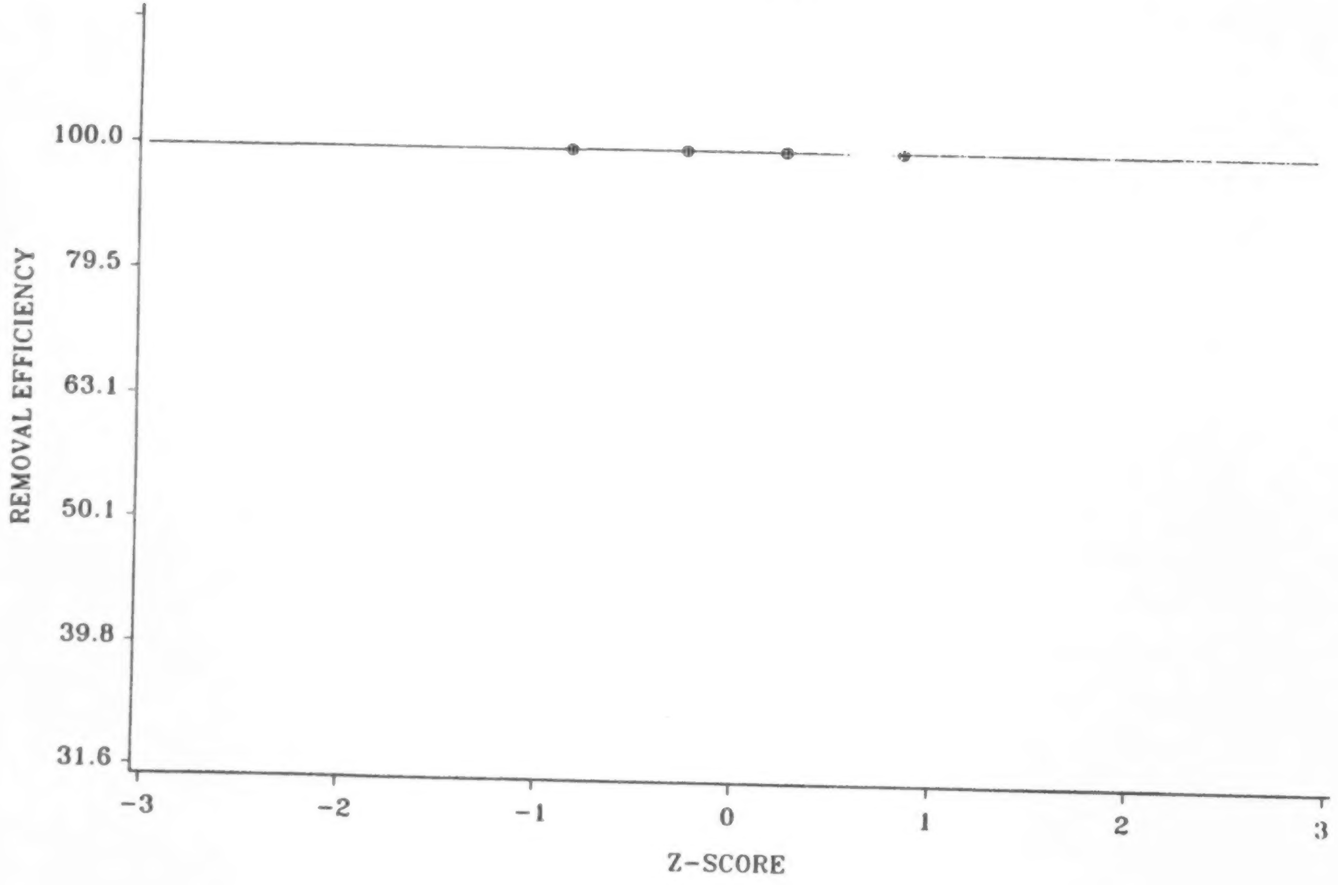
POLLUTANT=PHOSPHORUS



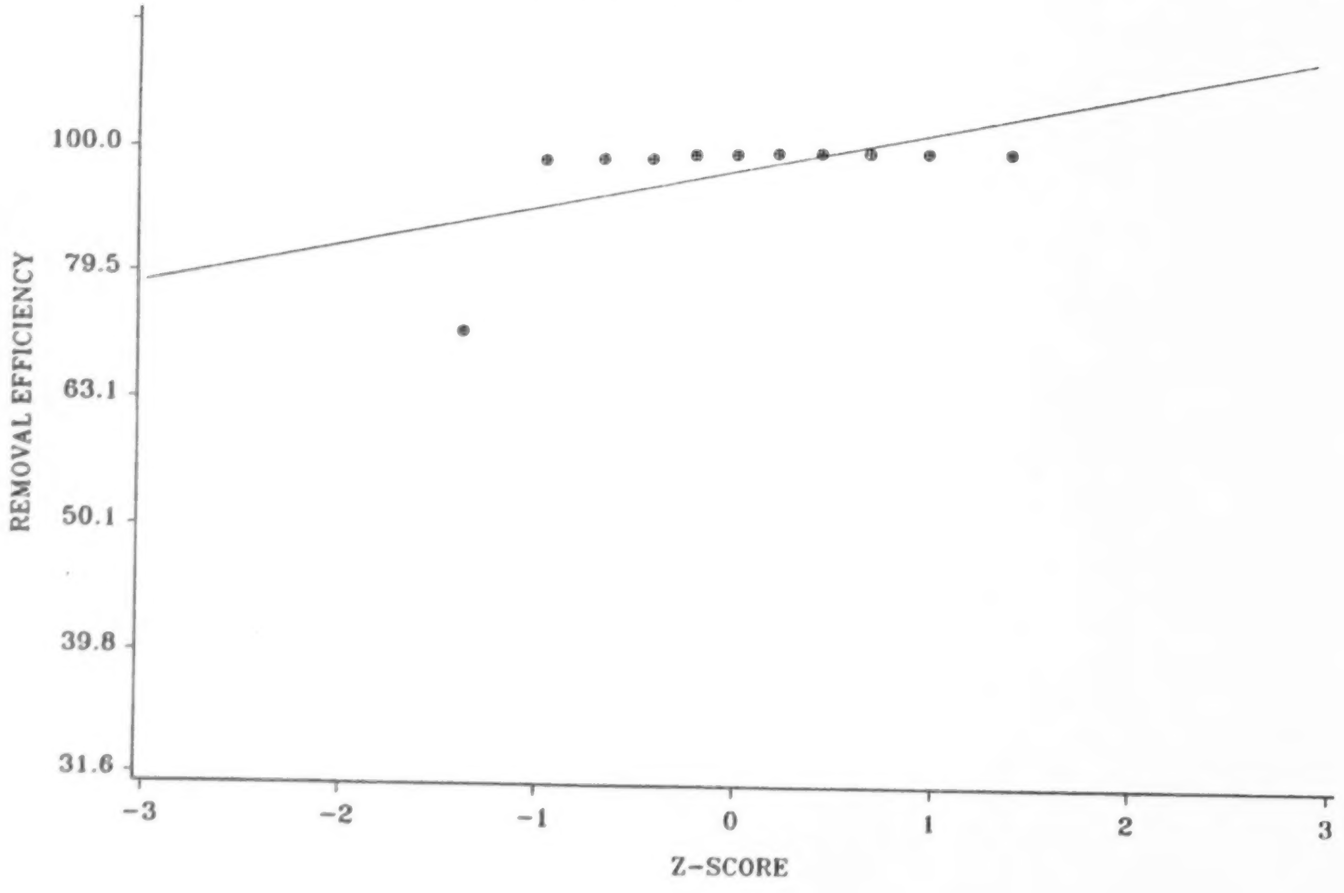
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT


POLLUTANT=POTASSIUM
REMOVAL EFFICIENCY
100.0
79.5
63.1
50.1
39.8
31.6
-3
-2
-1
0
1
2
3
Z-SCORE
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=SILICON



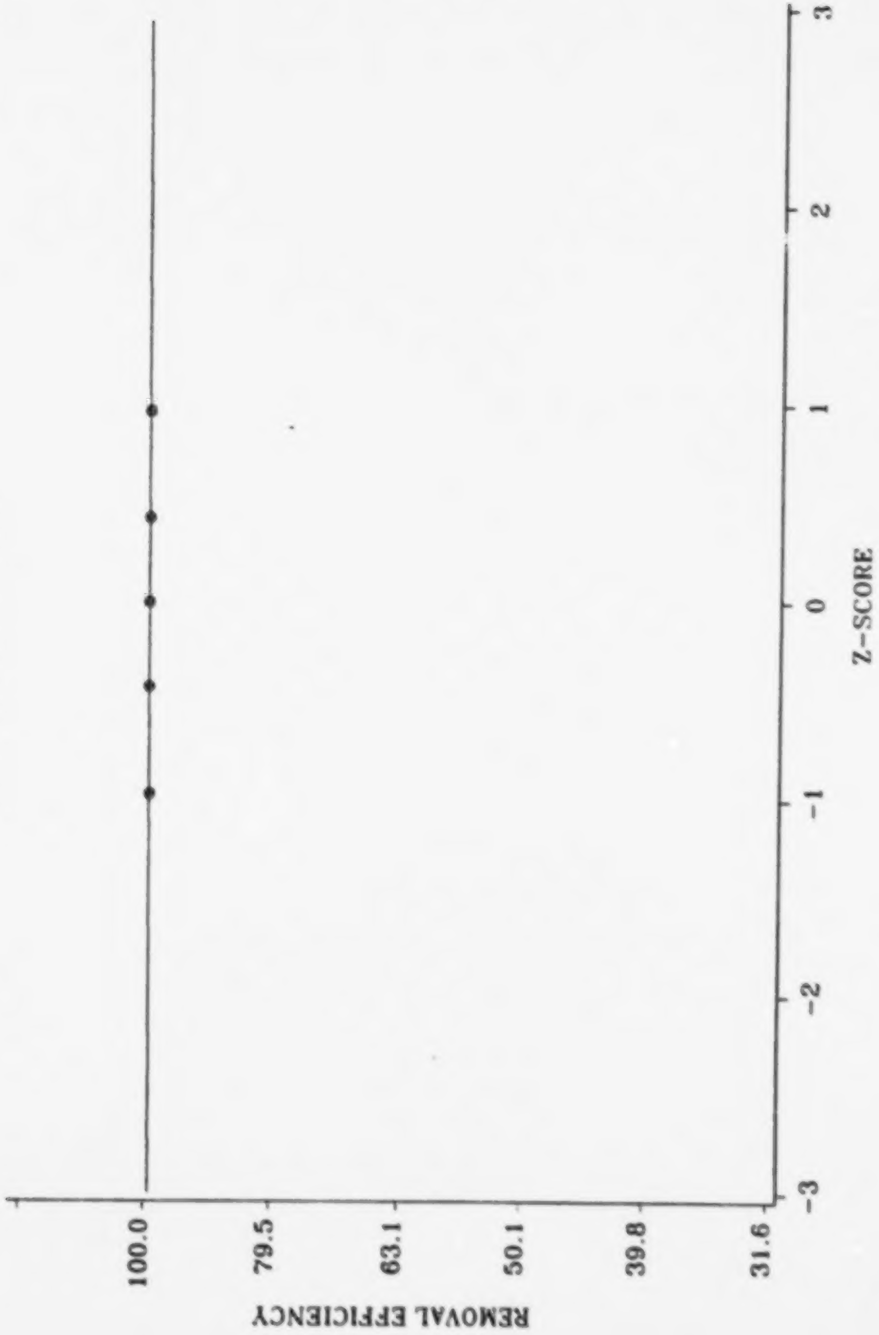
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT



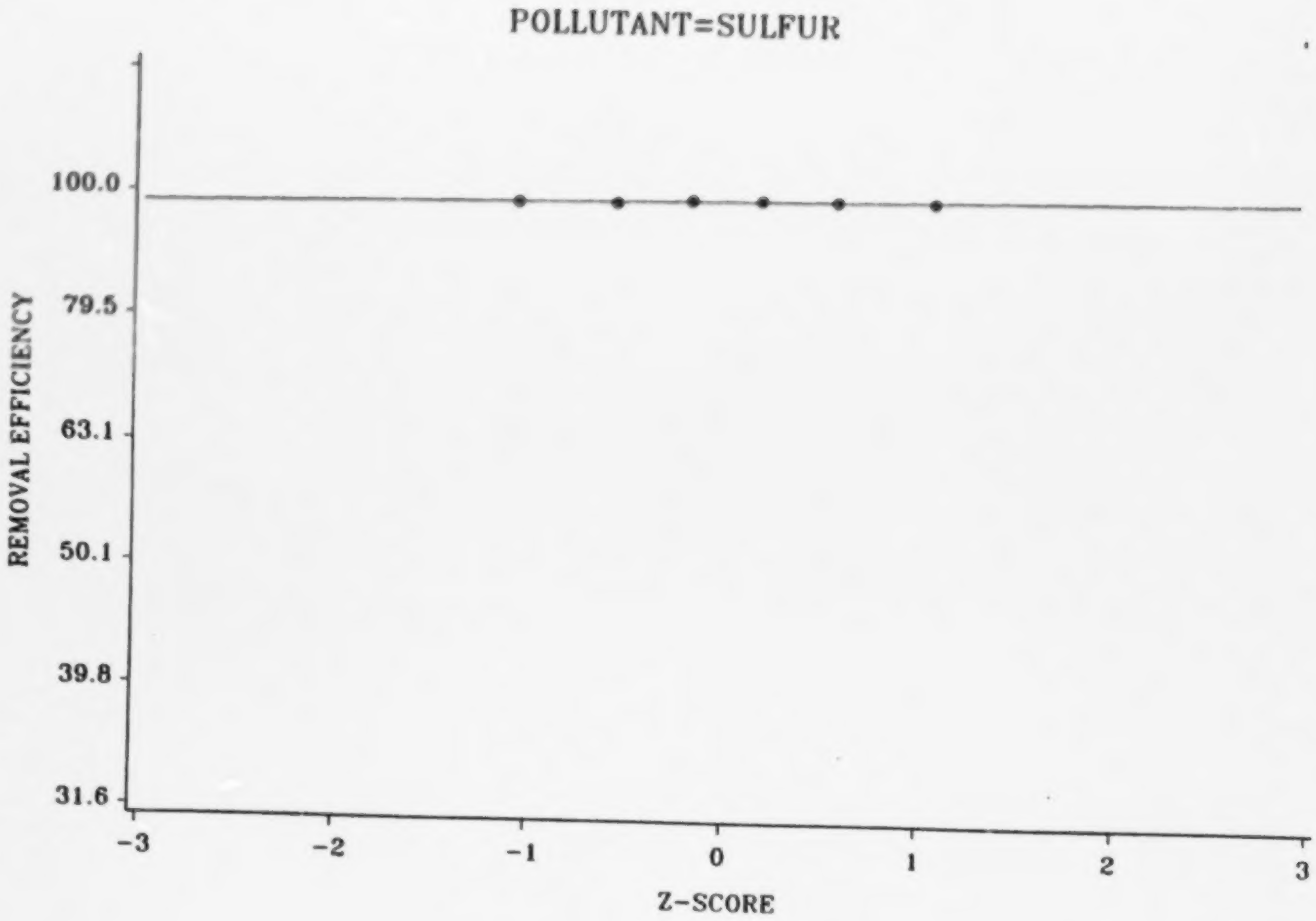
POLLUTANT=SILVER

TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=SODIUM

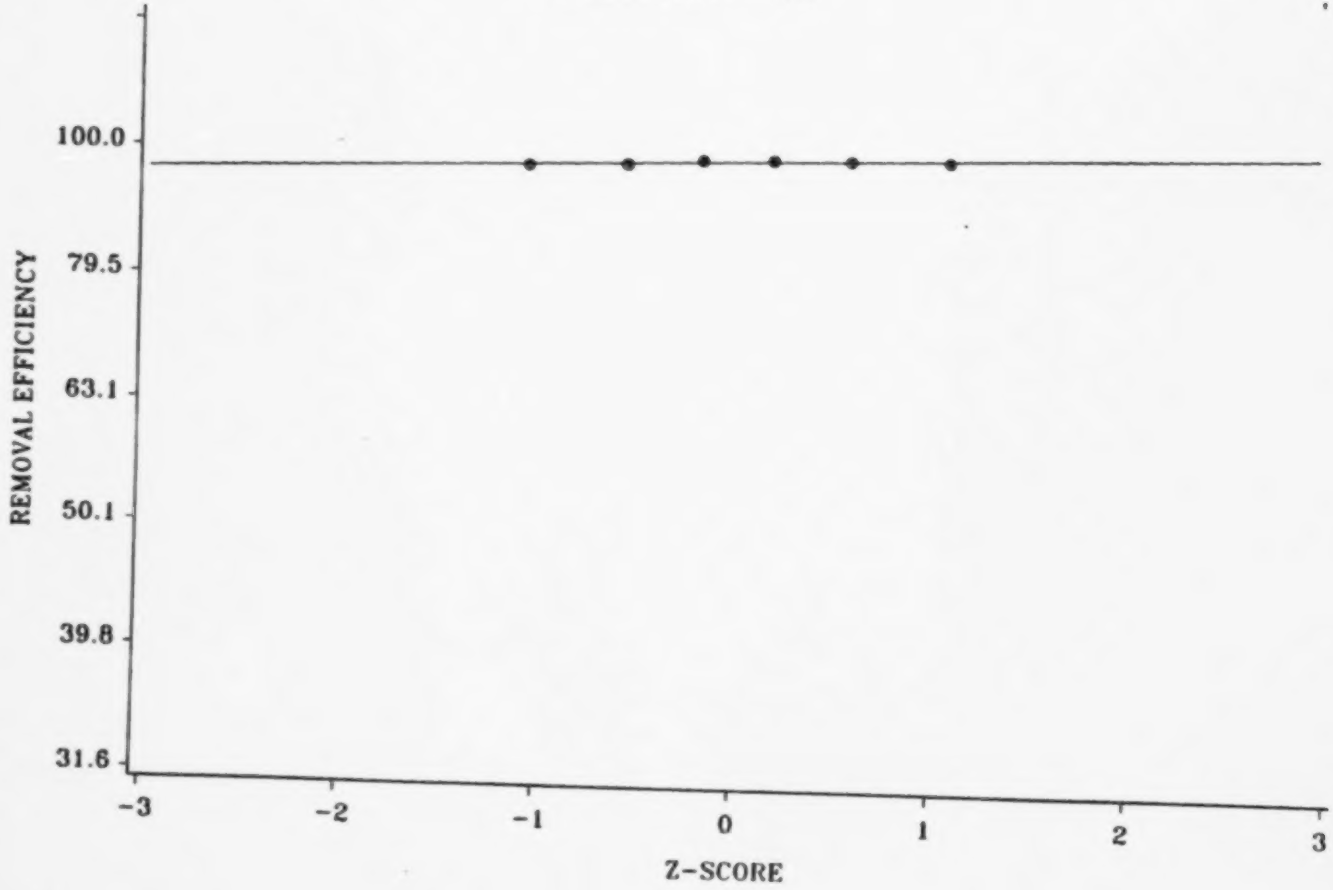


TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT



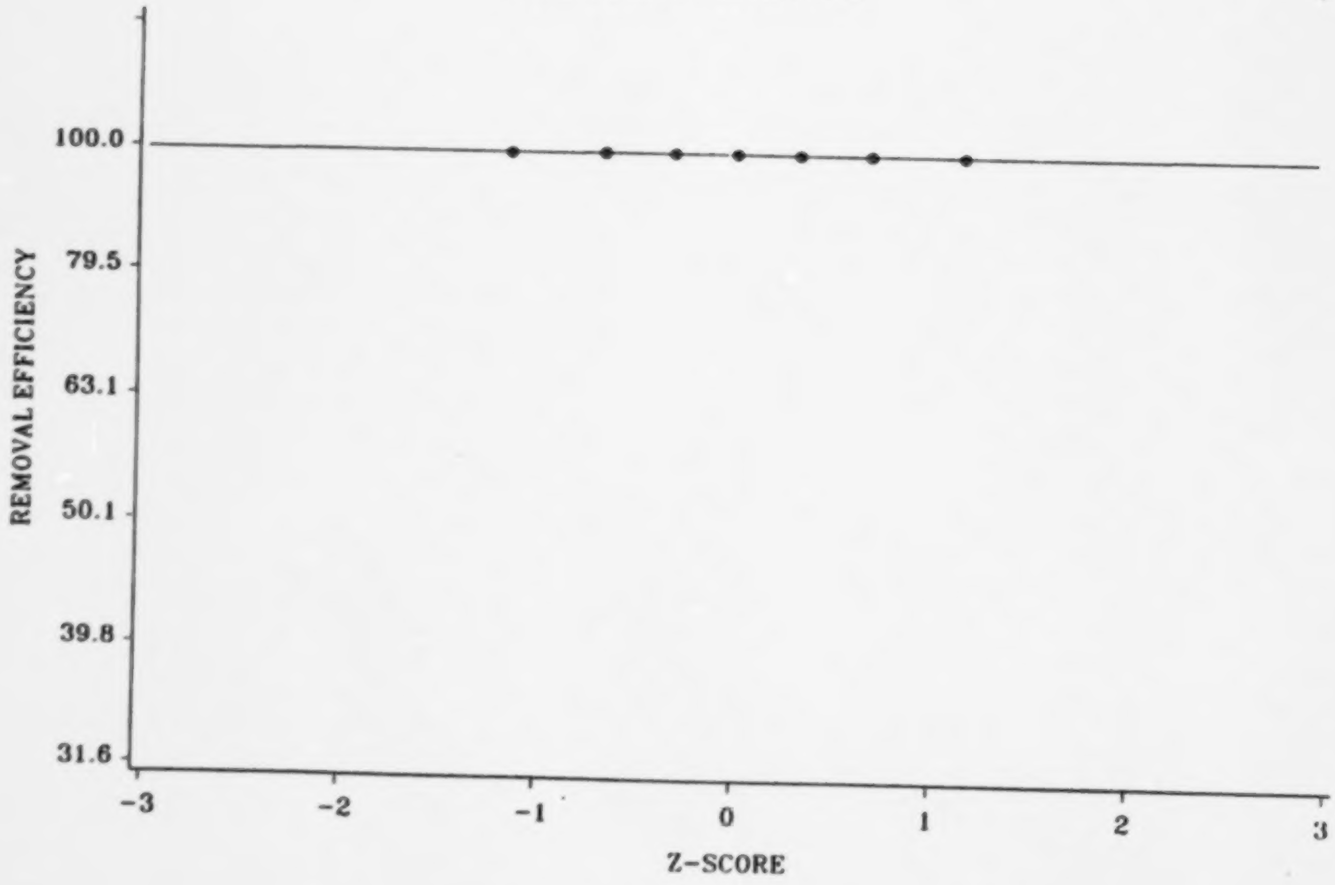
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=TIN



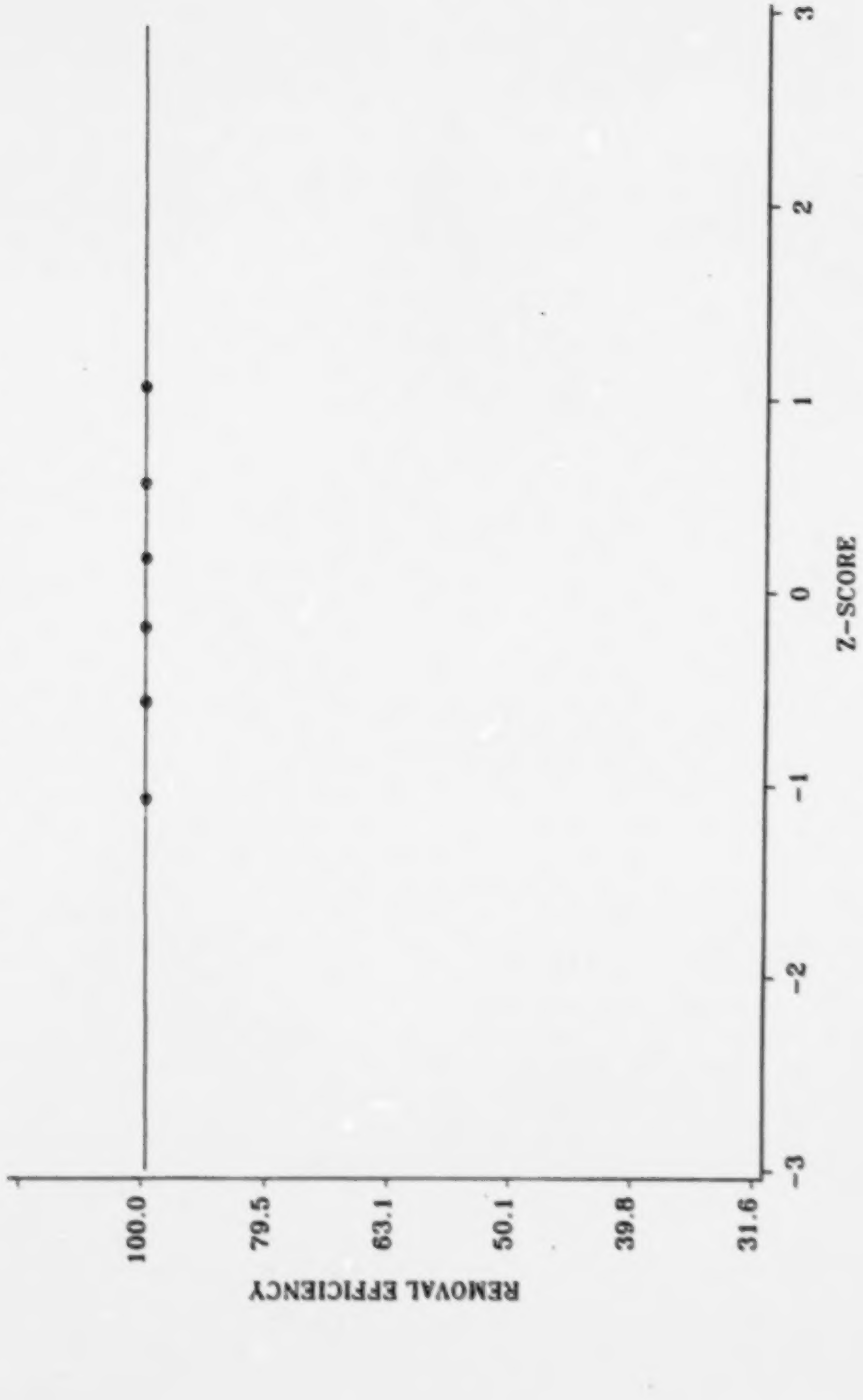
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=TITANIUM



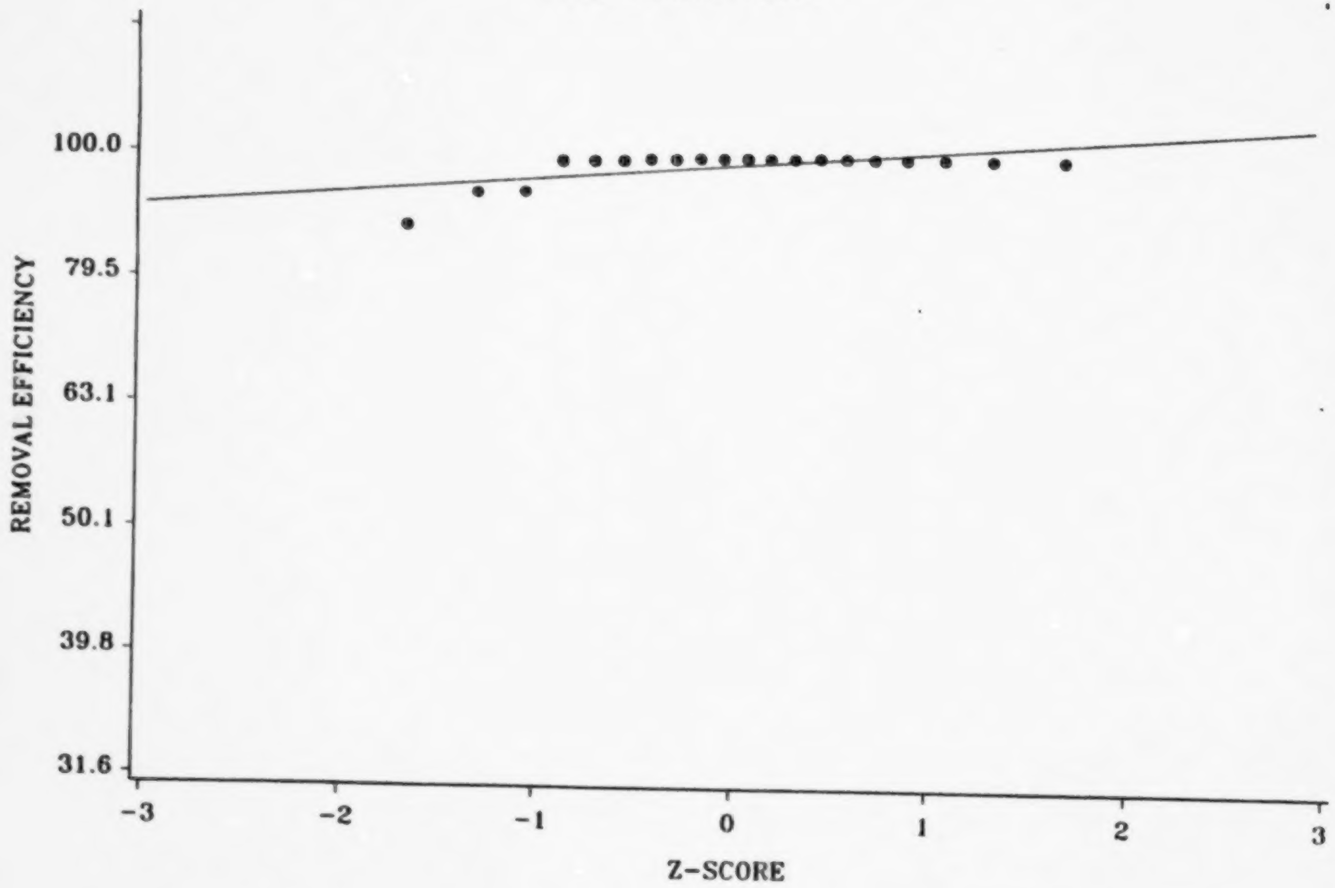
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=VANADIUM



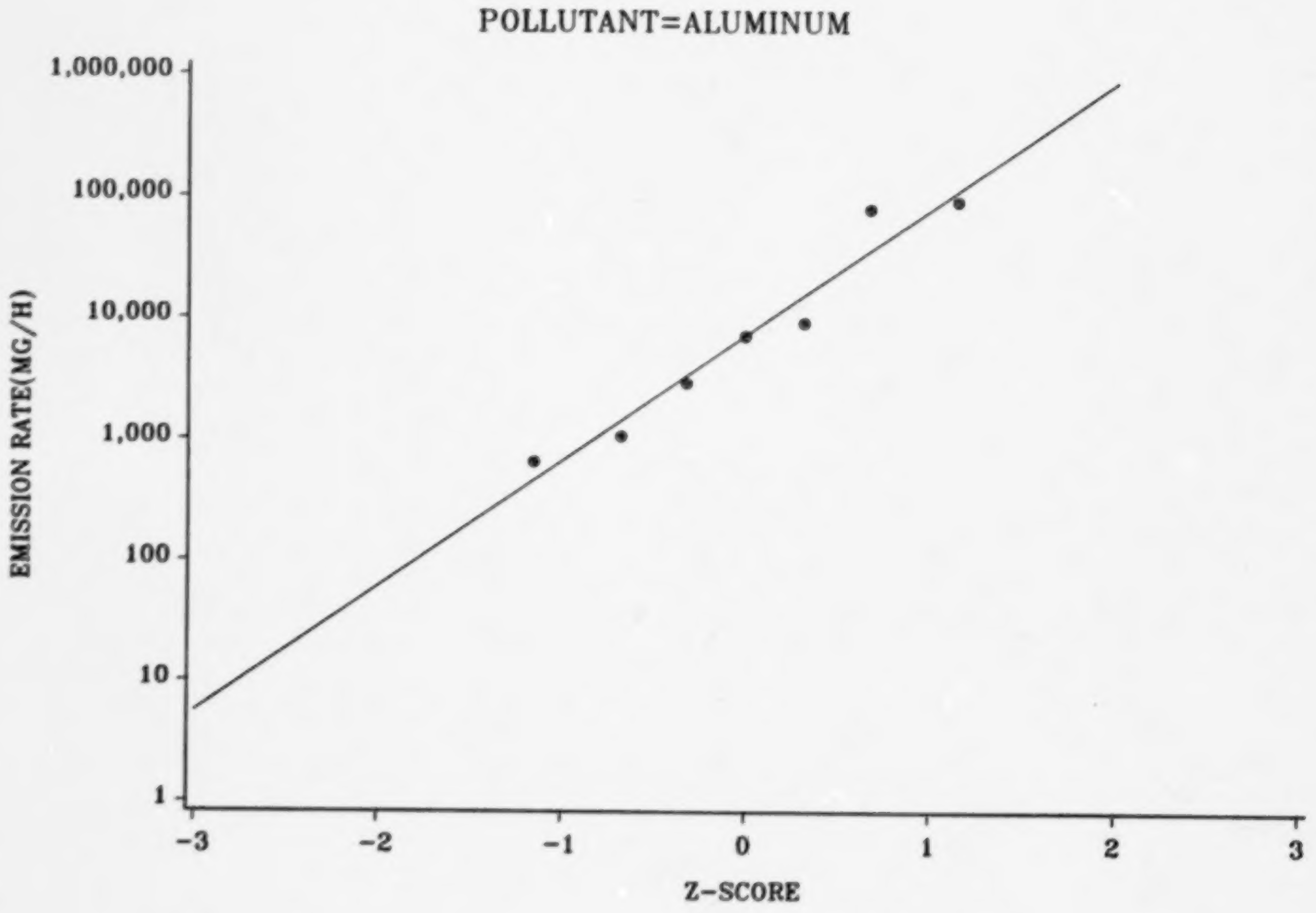
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=ZINC



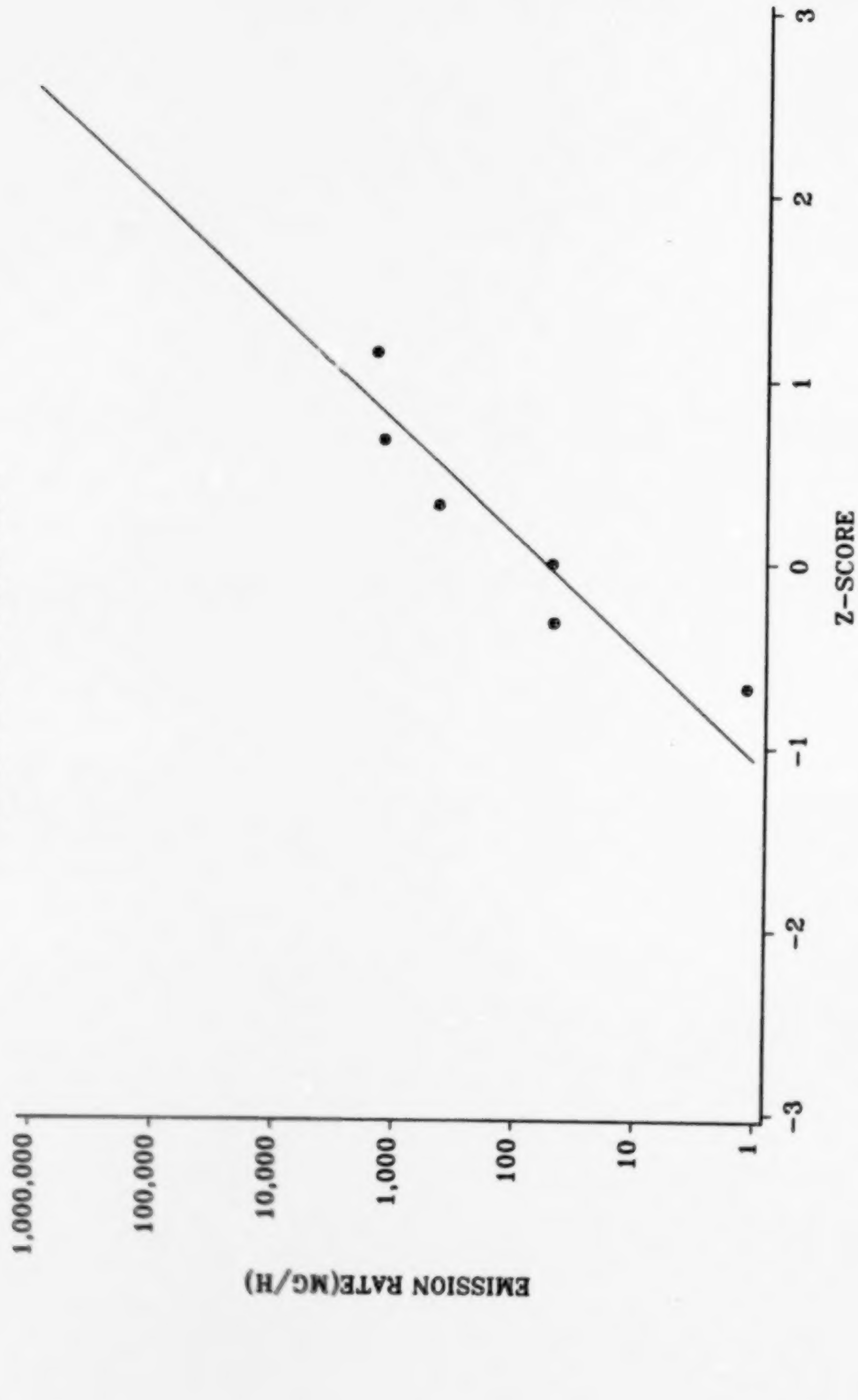
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

APPENDIX A-2

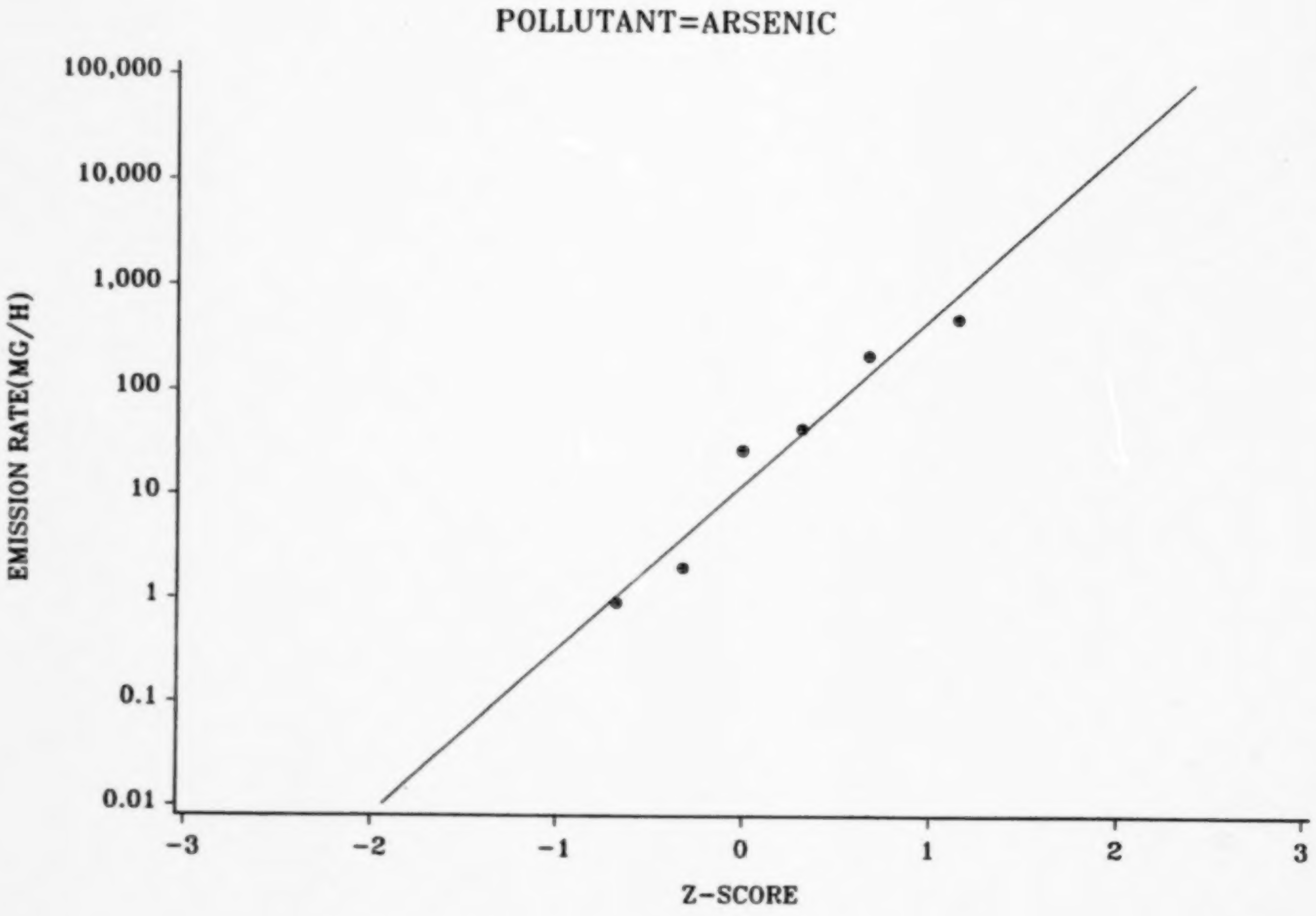


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=ANTIMONY

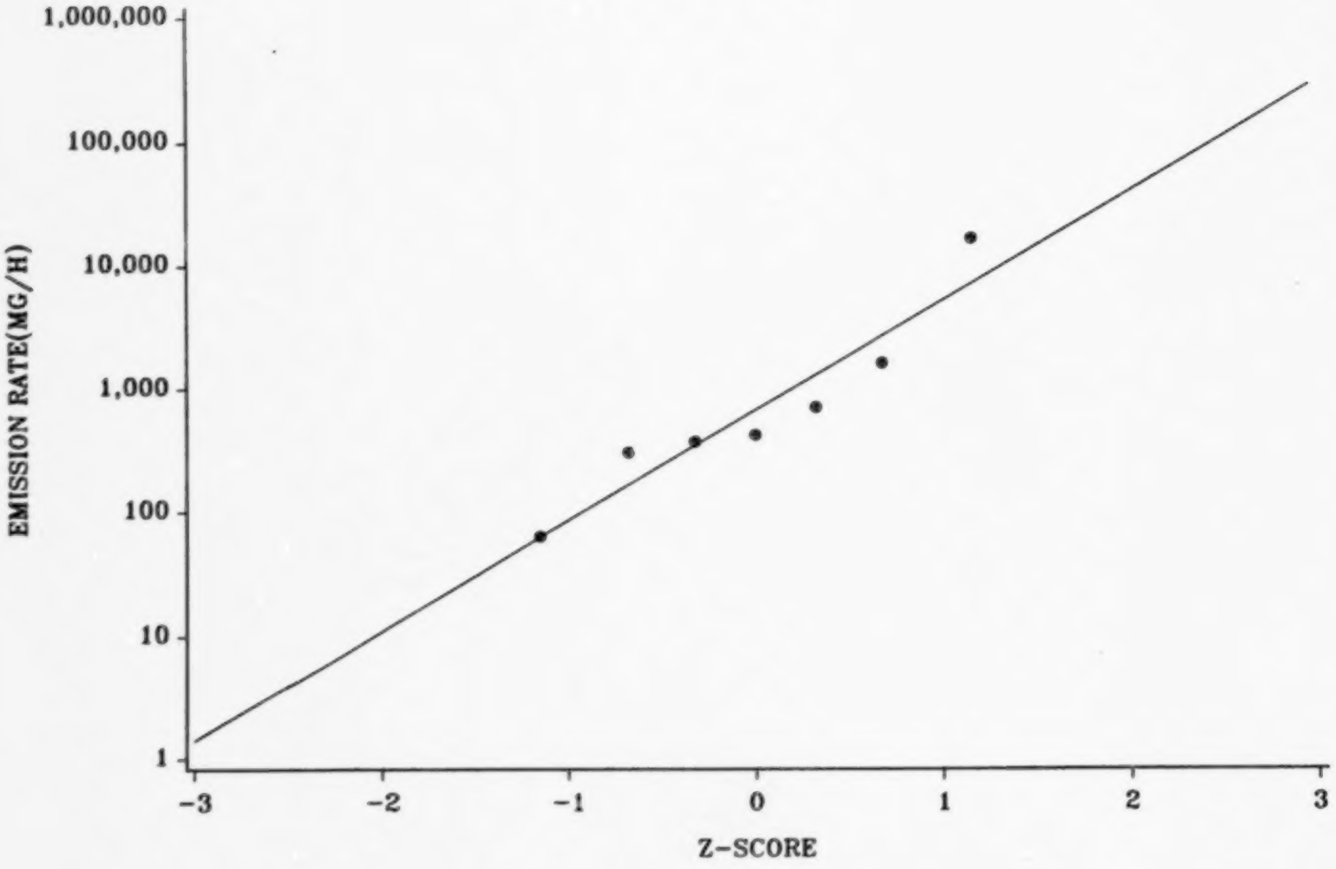


TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT



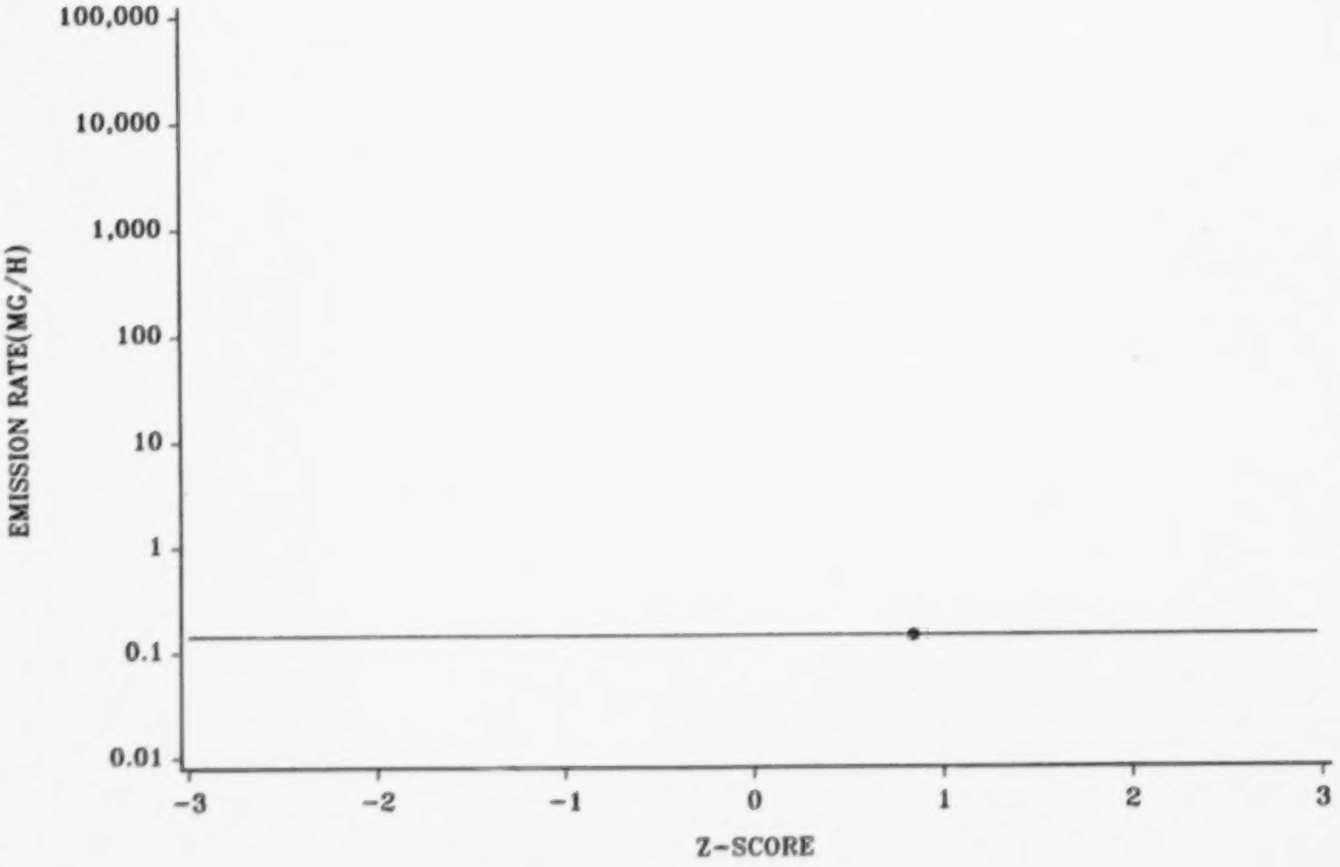
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=BARIUM



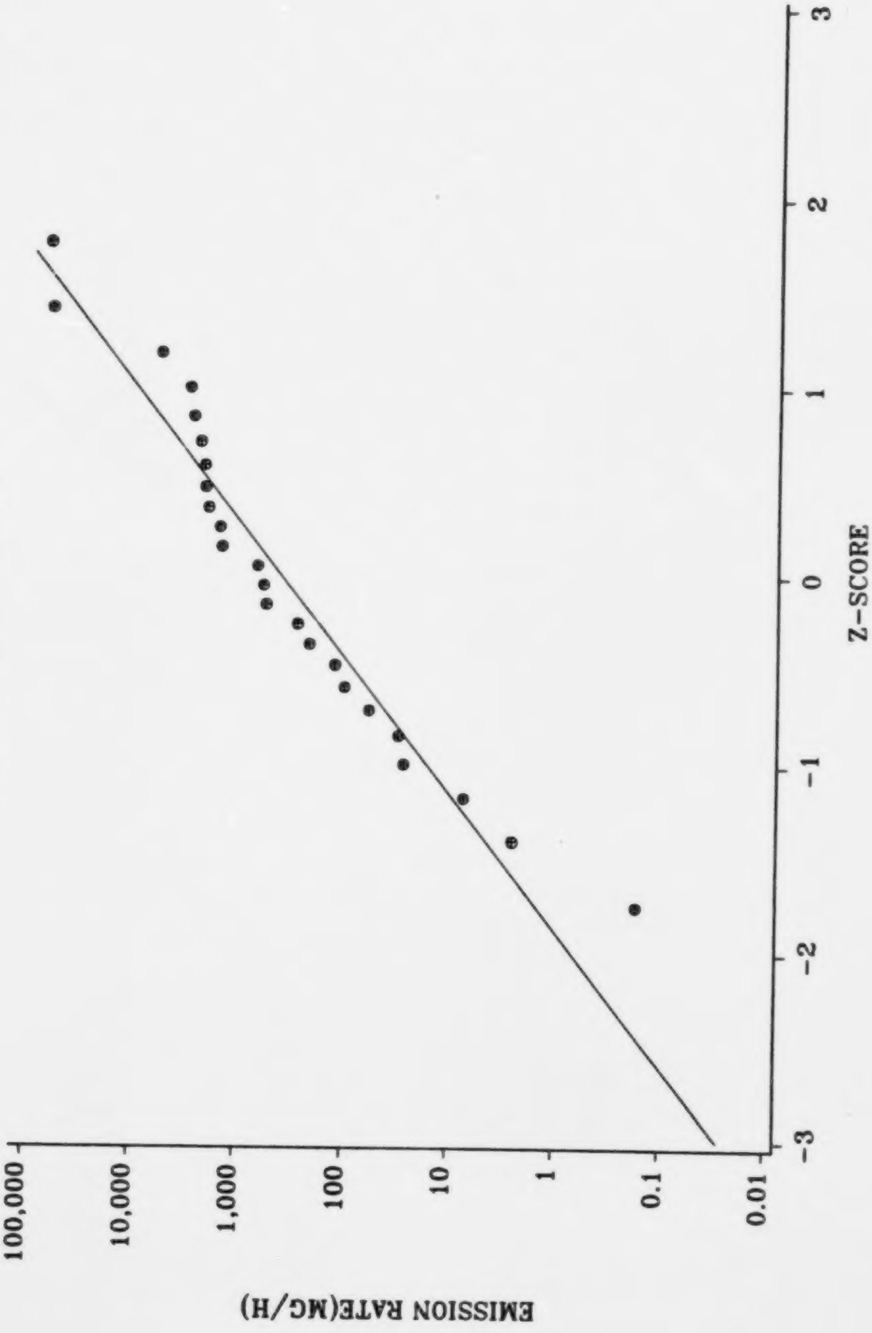
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=BERYLLIUM

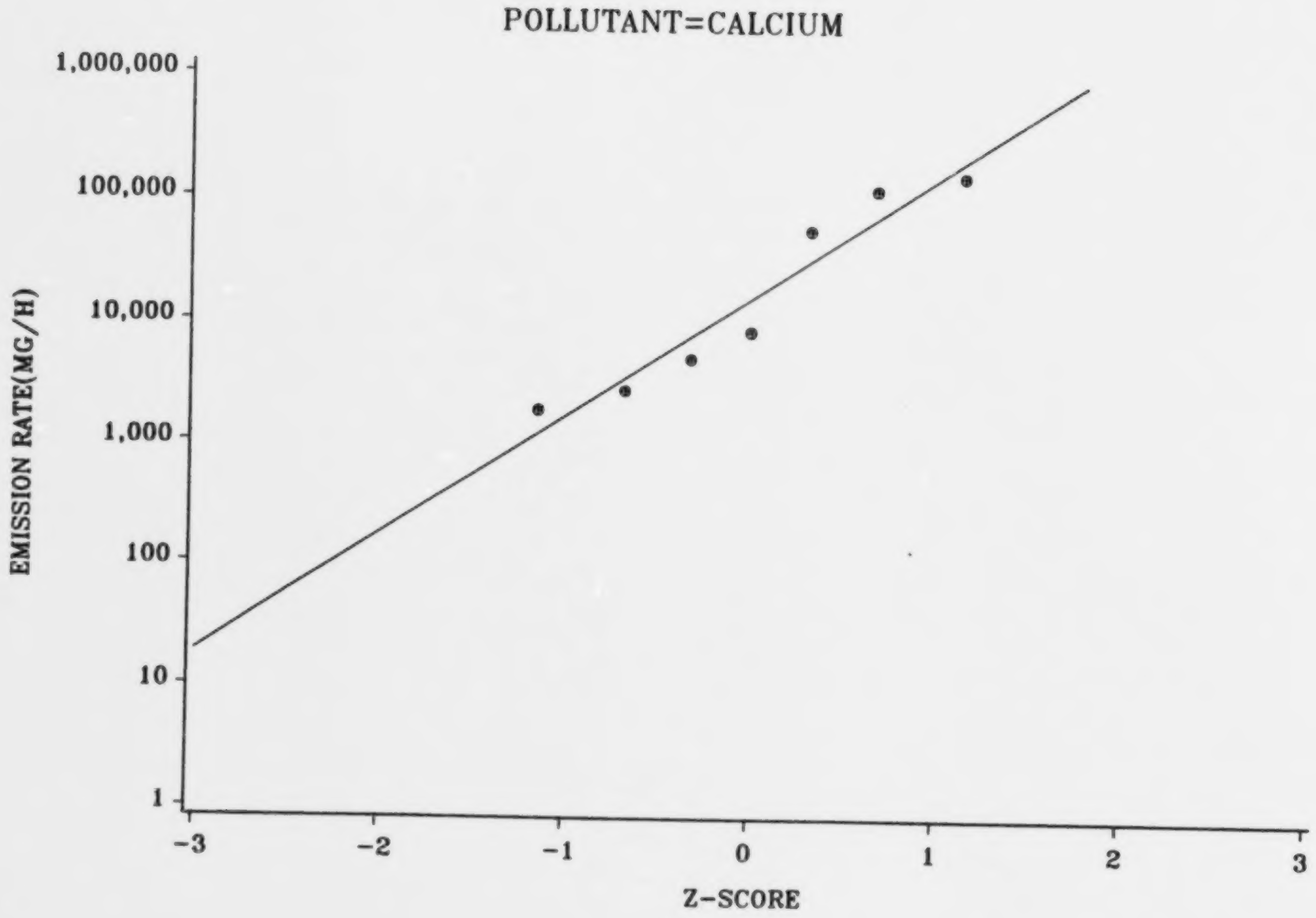


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=CADMIUM

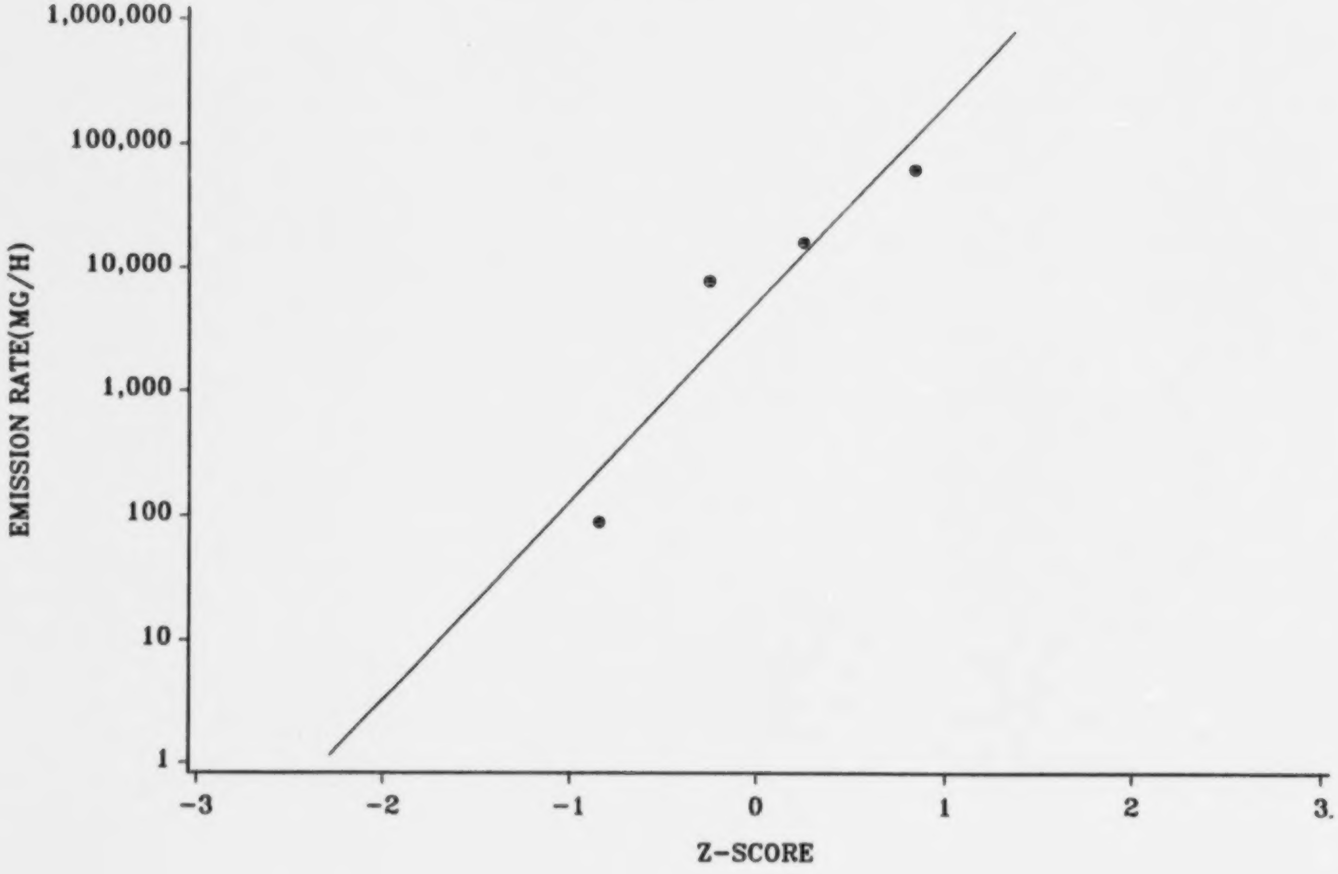


TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT



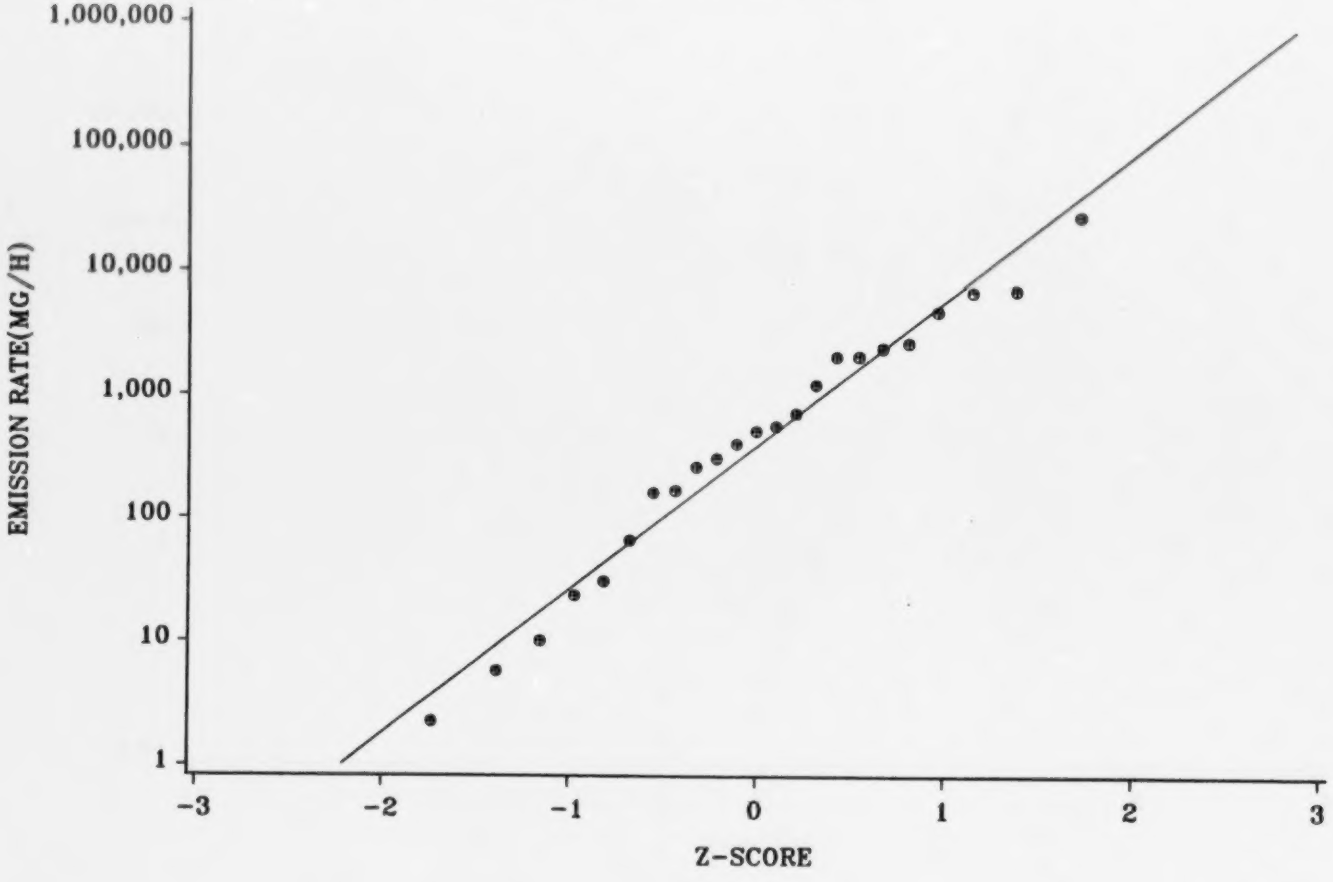
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=CHLORINE

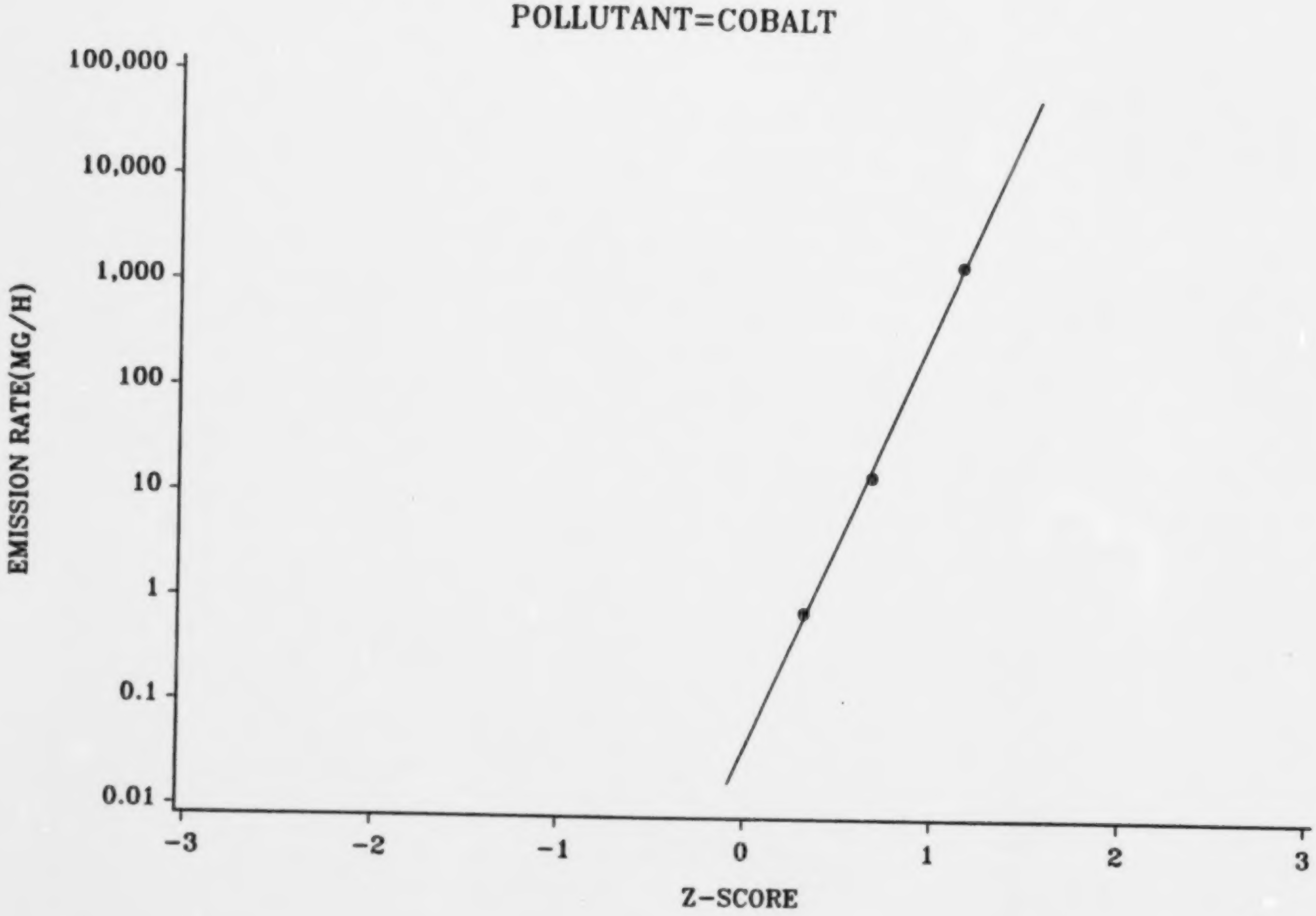


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=CHROMIUM

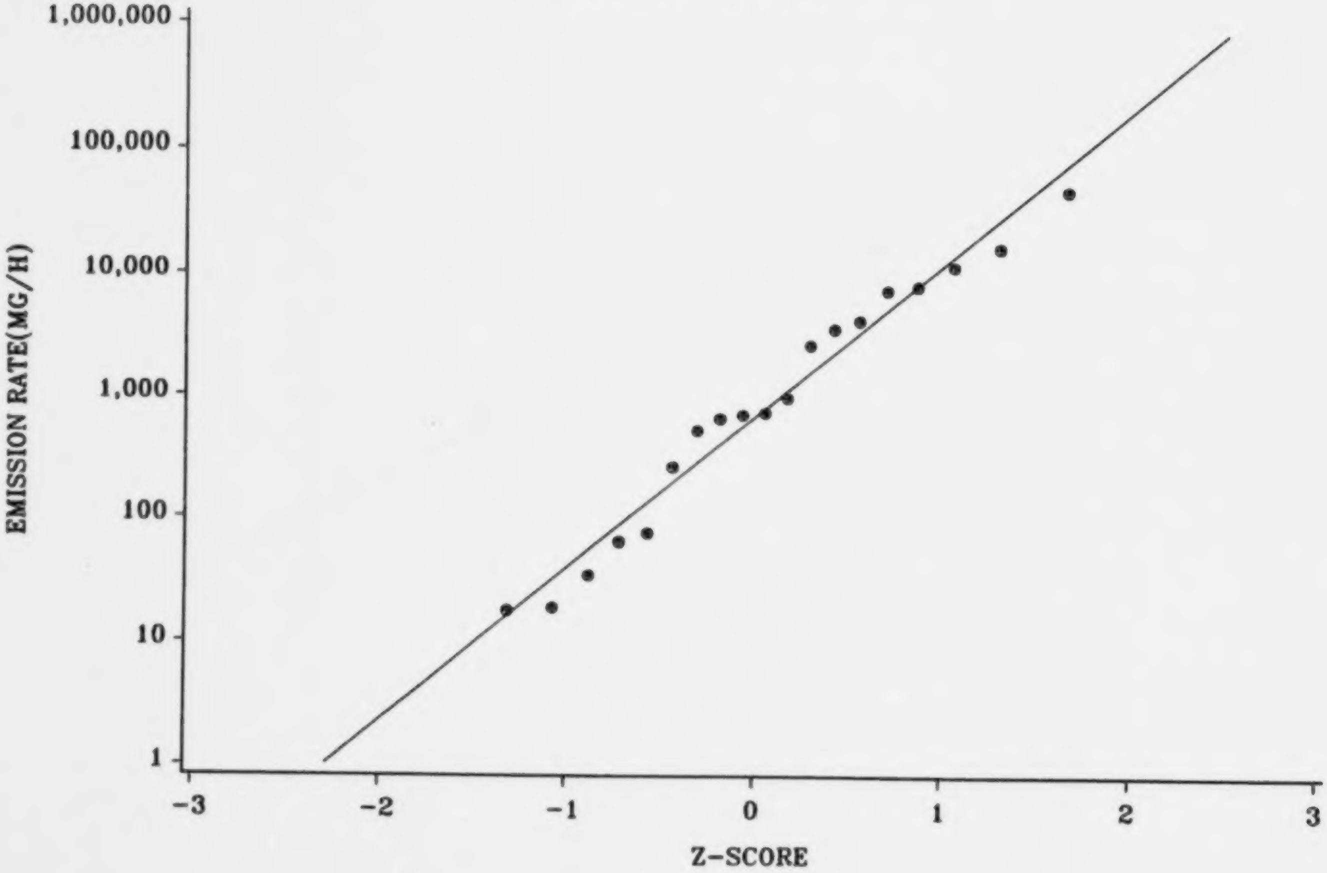


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT



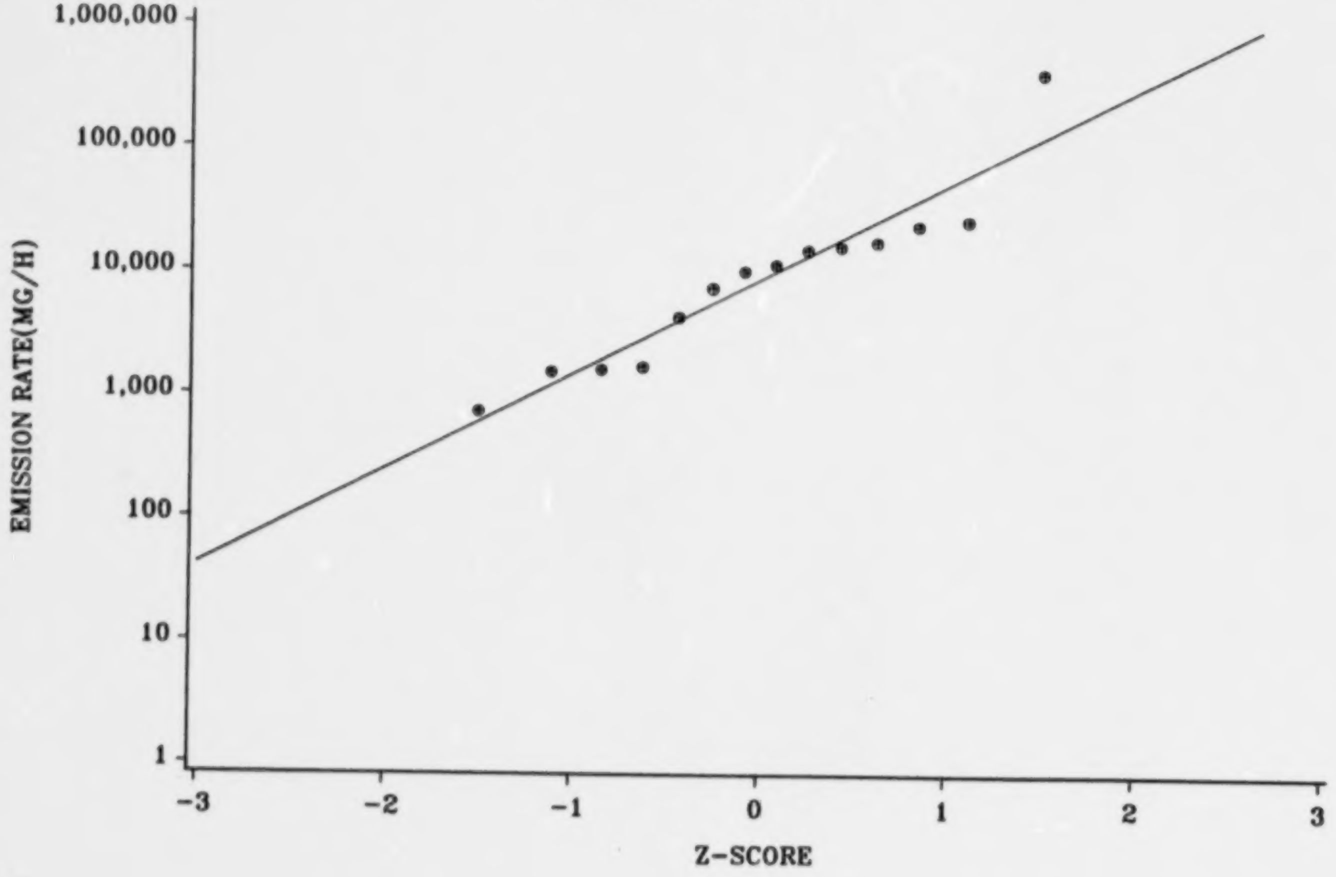
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=COPPER

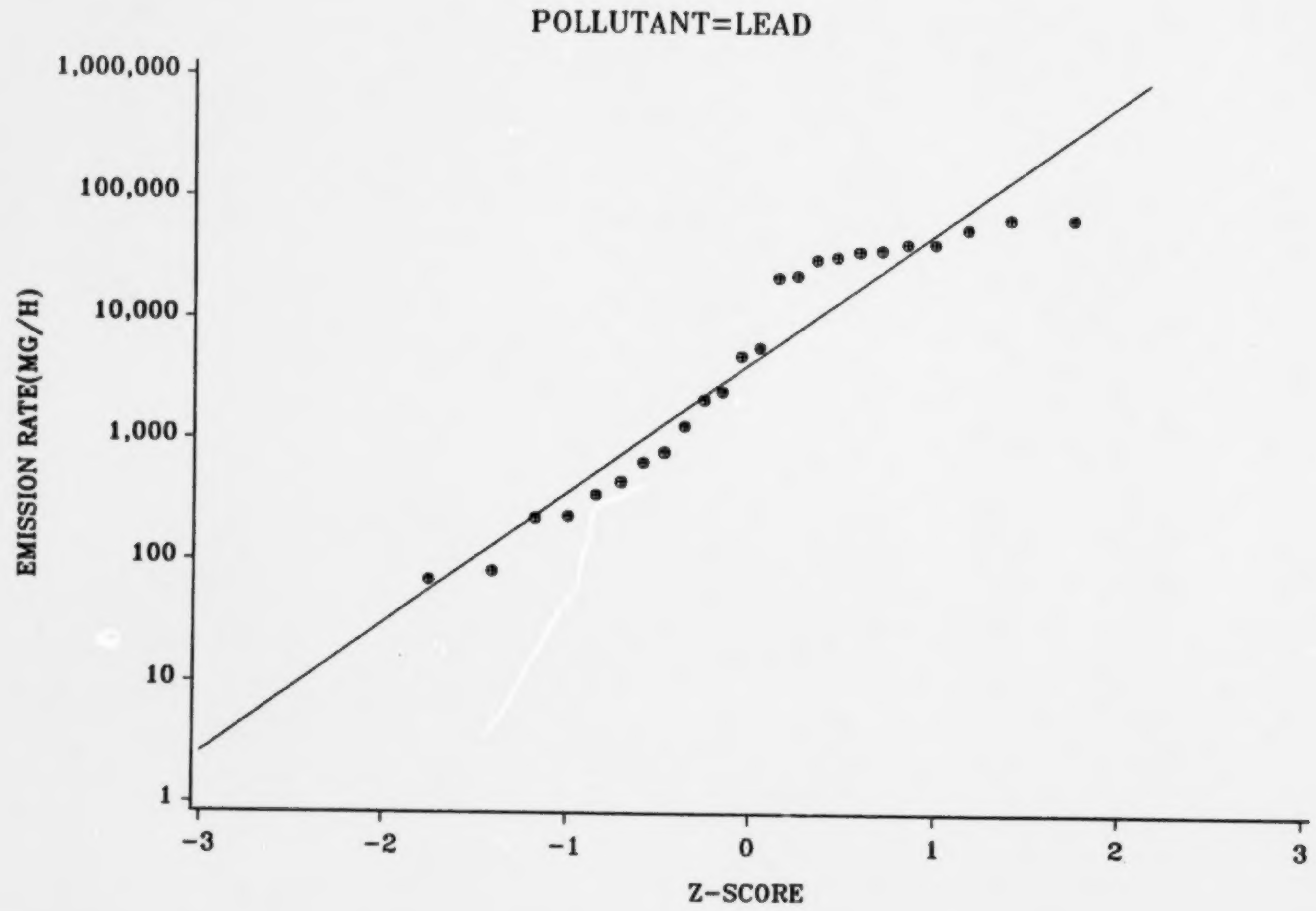


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=IRON

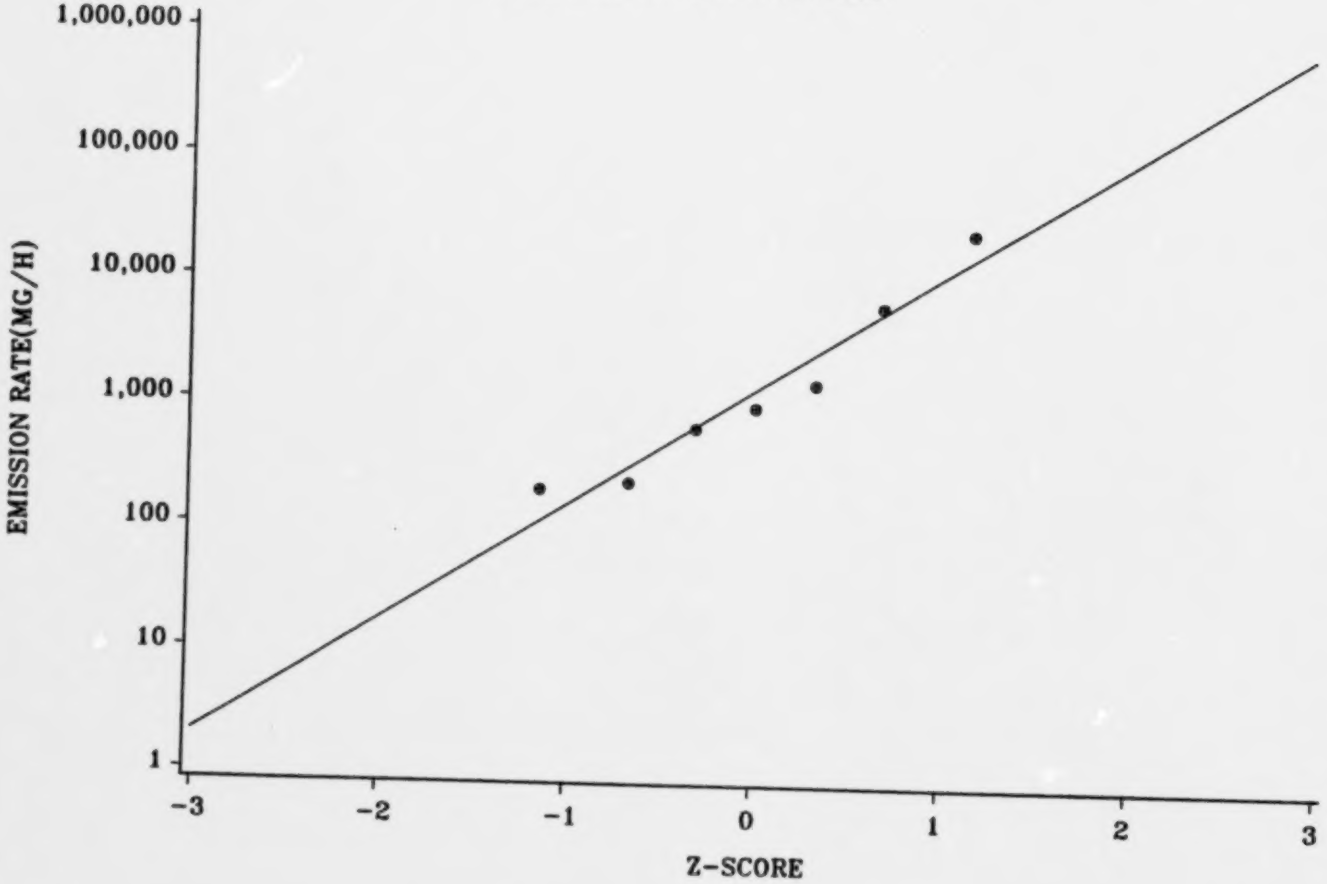


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

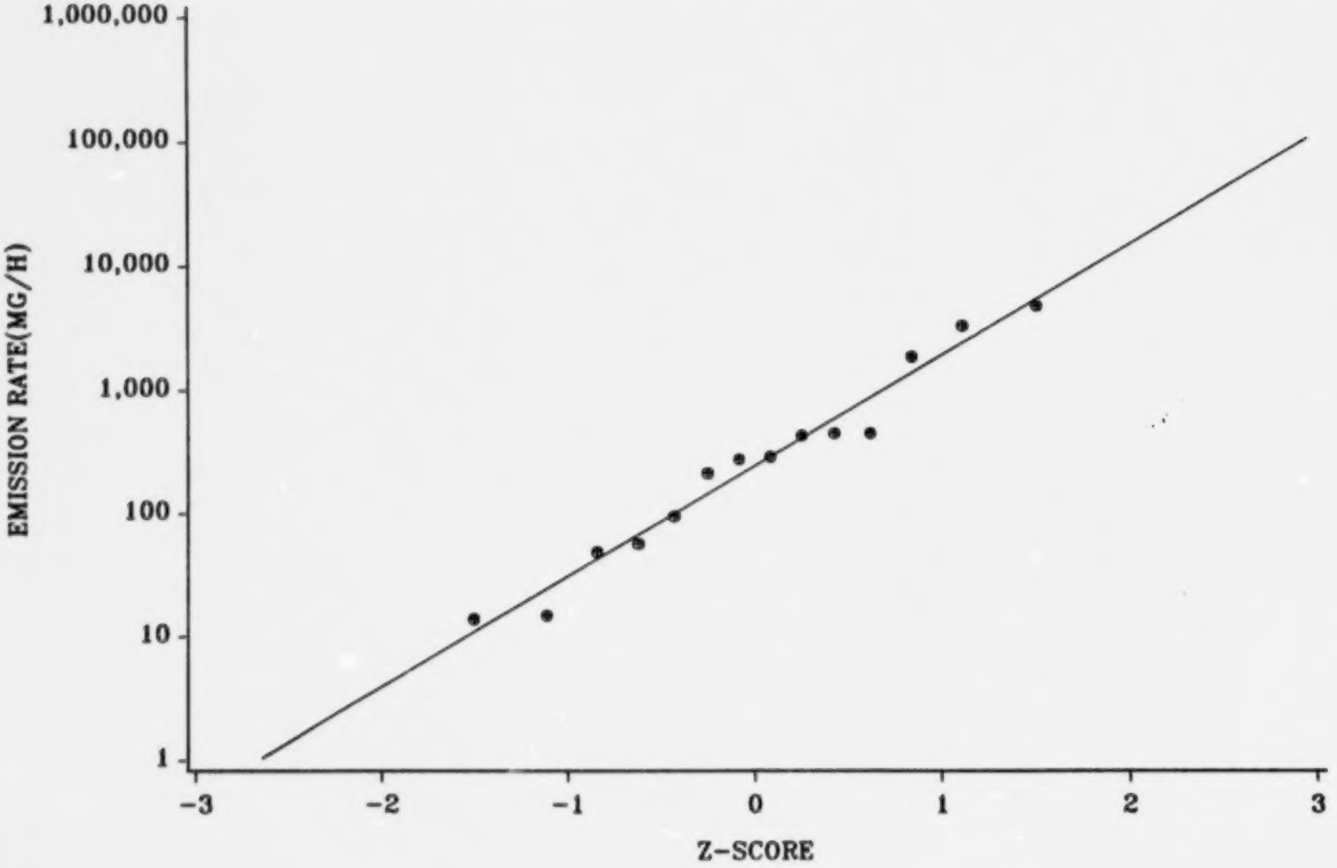


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=MAGNESIUM

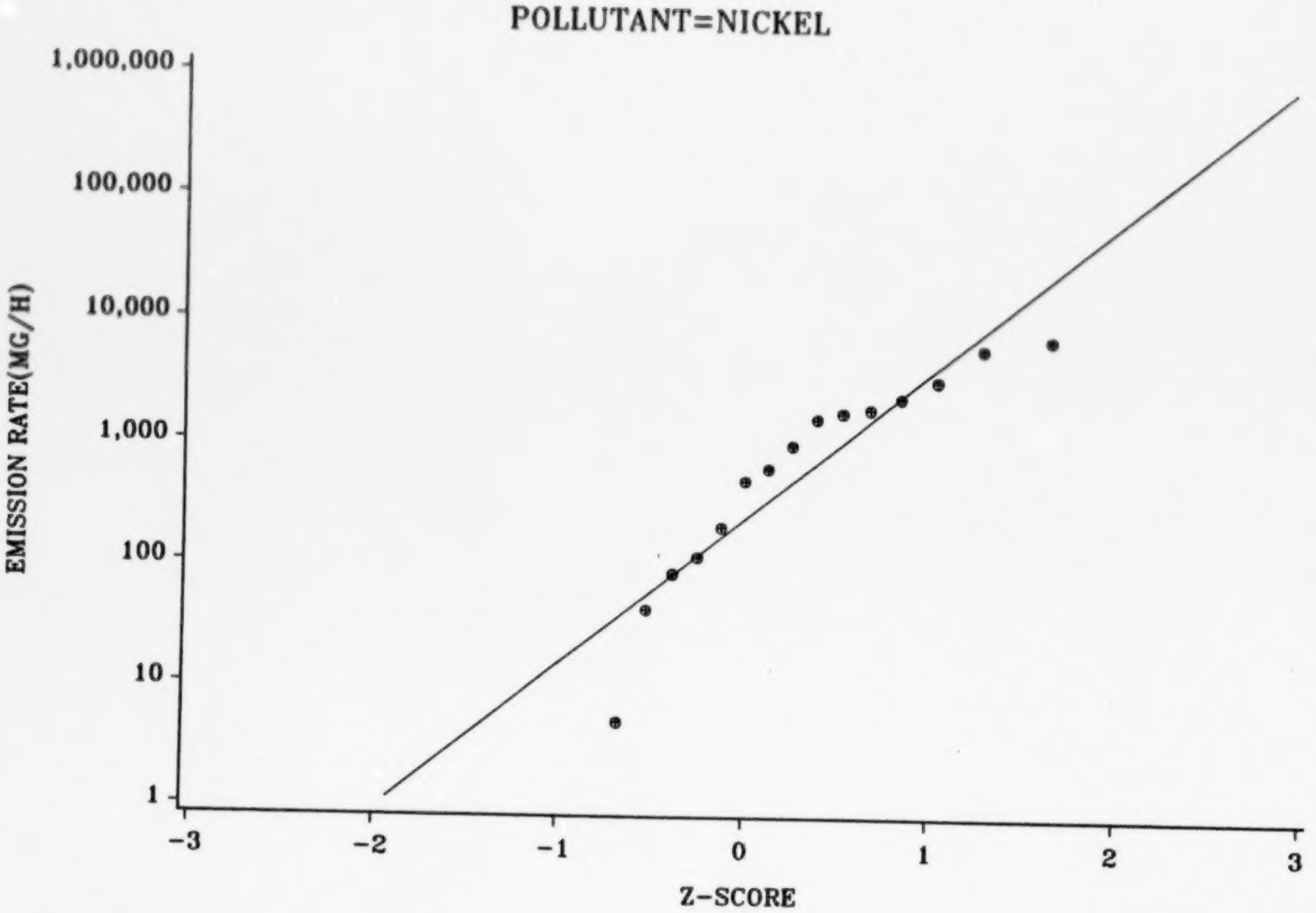


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT



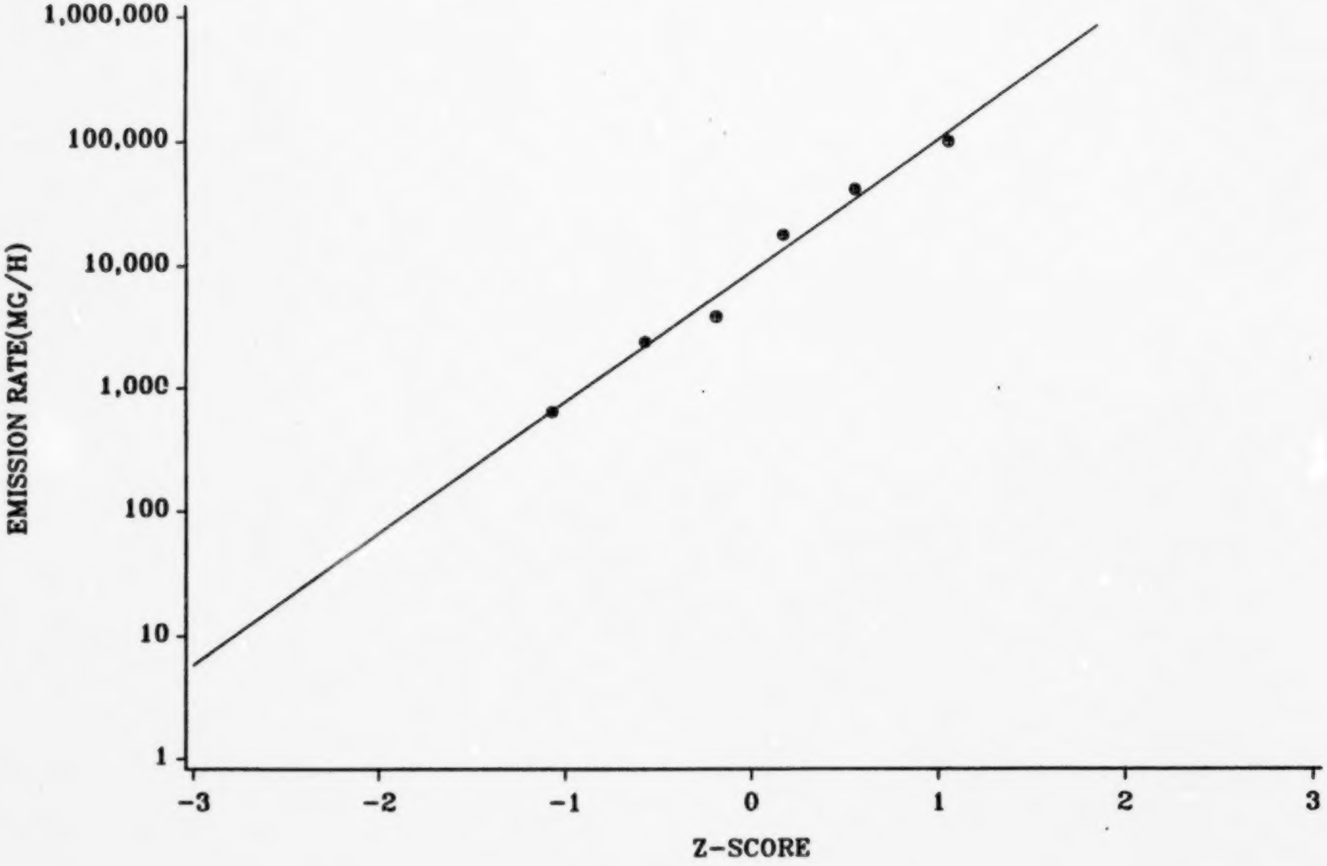
POLLUTANT=MANGANESE

TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

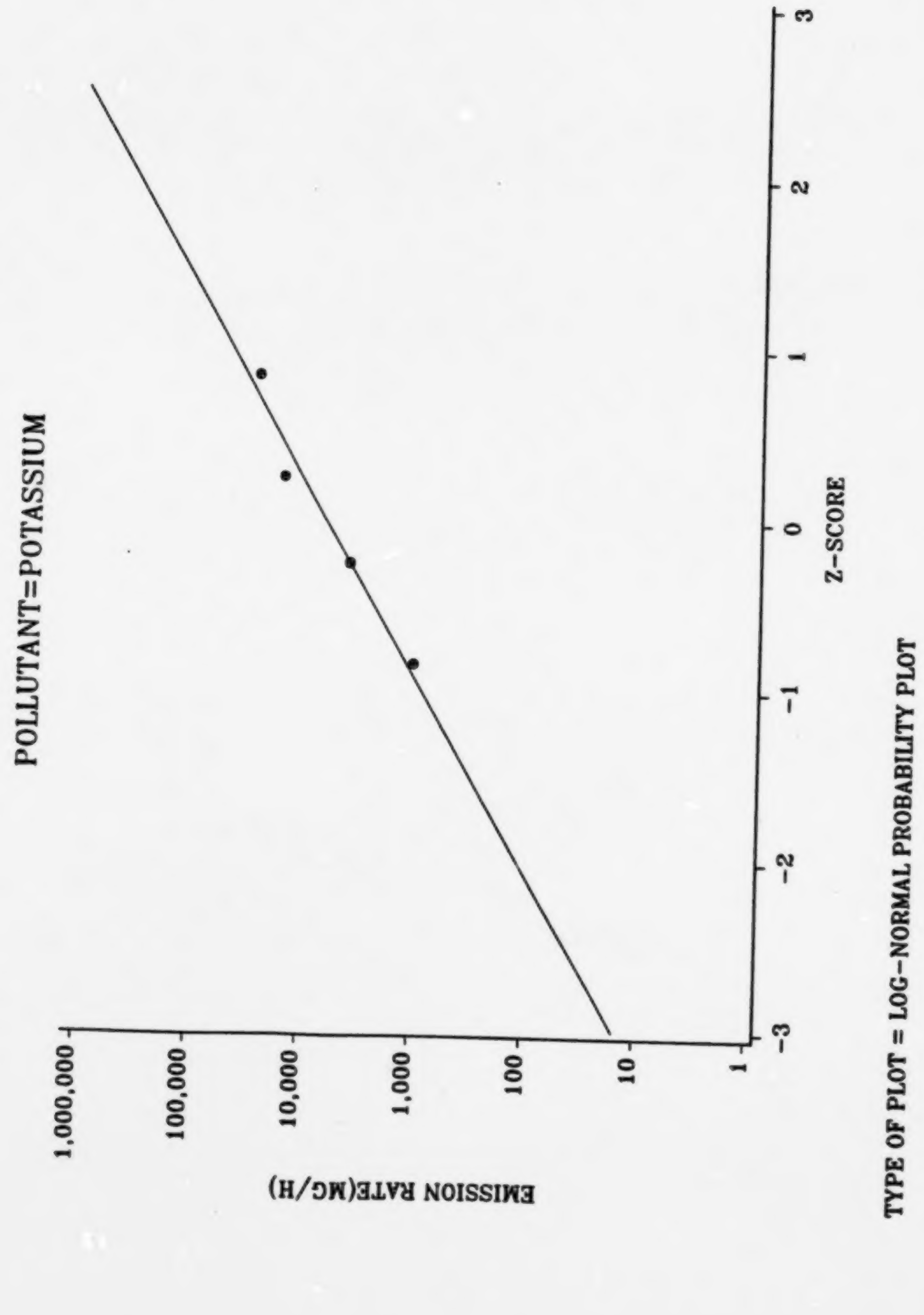


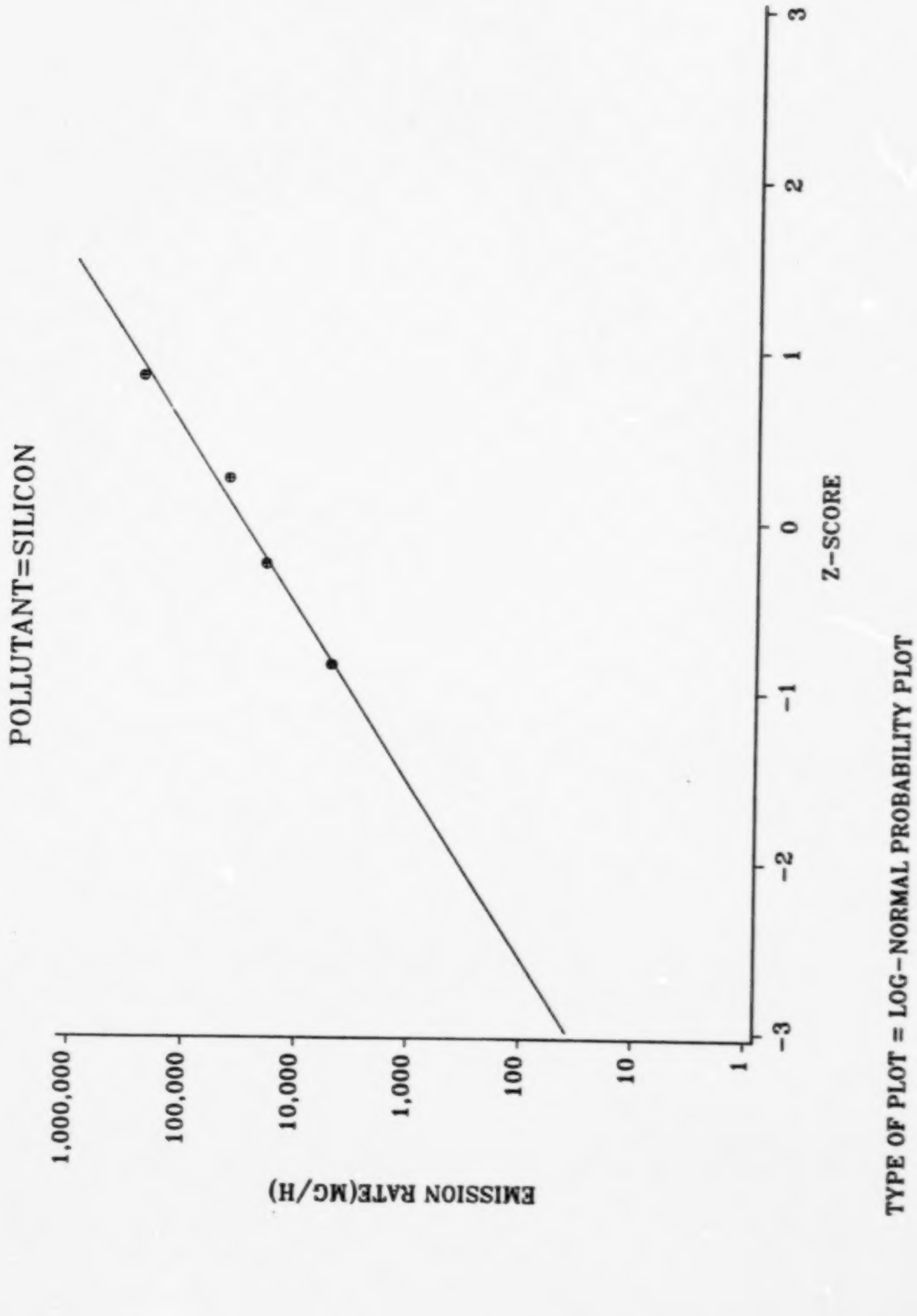
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

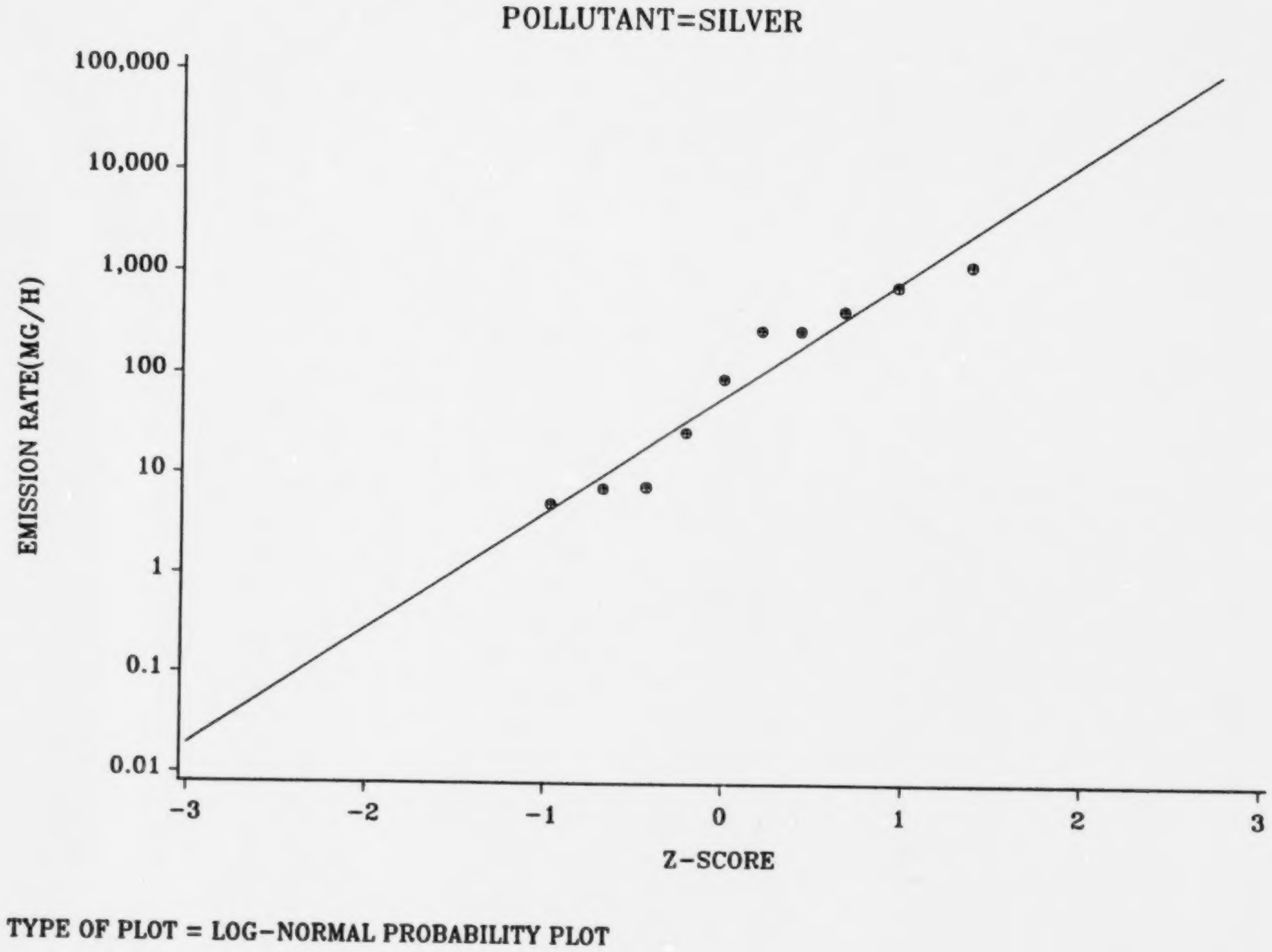
POLLUTANT=PHOSPHORUS



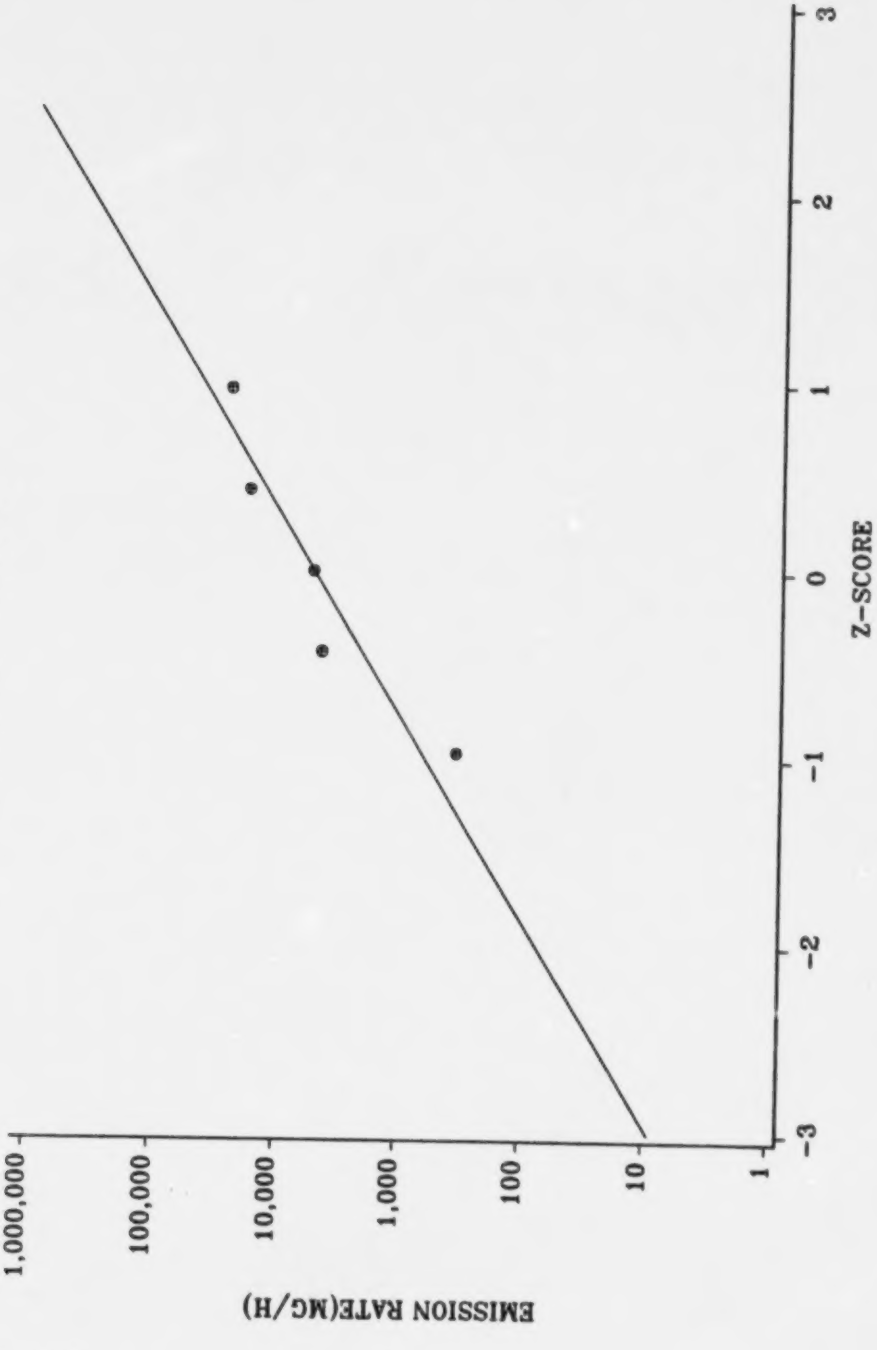
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT


POLLUTANT=POTASSIUM
EMISSION RATE(MG/H)
1,000,000
100,000
10,000
1,000
100
10
1
-3
-2
-1
0
1
2
3
Z-SCORE
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT


POLLUTANT=SILICON
EMISSION RATE(MG/H)
1,000,000
100,000
10,000
1,000
100
10
1
−3
−2
−1
0
1
2
3
Z−SCORE
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

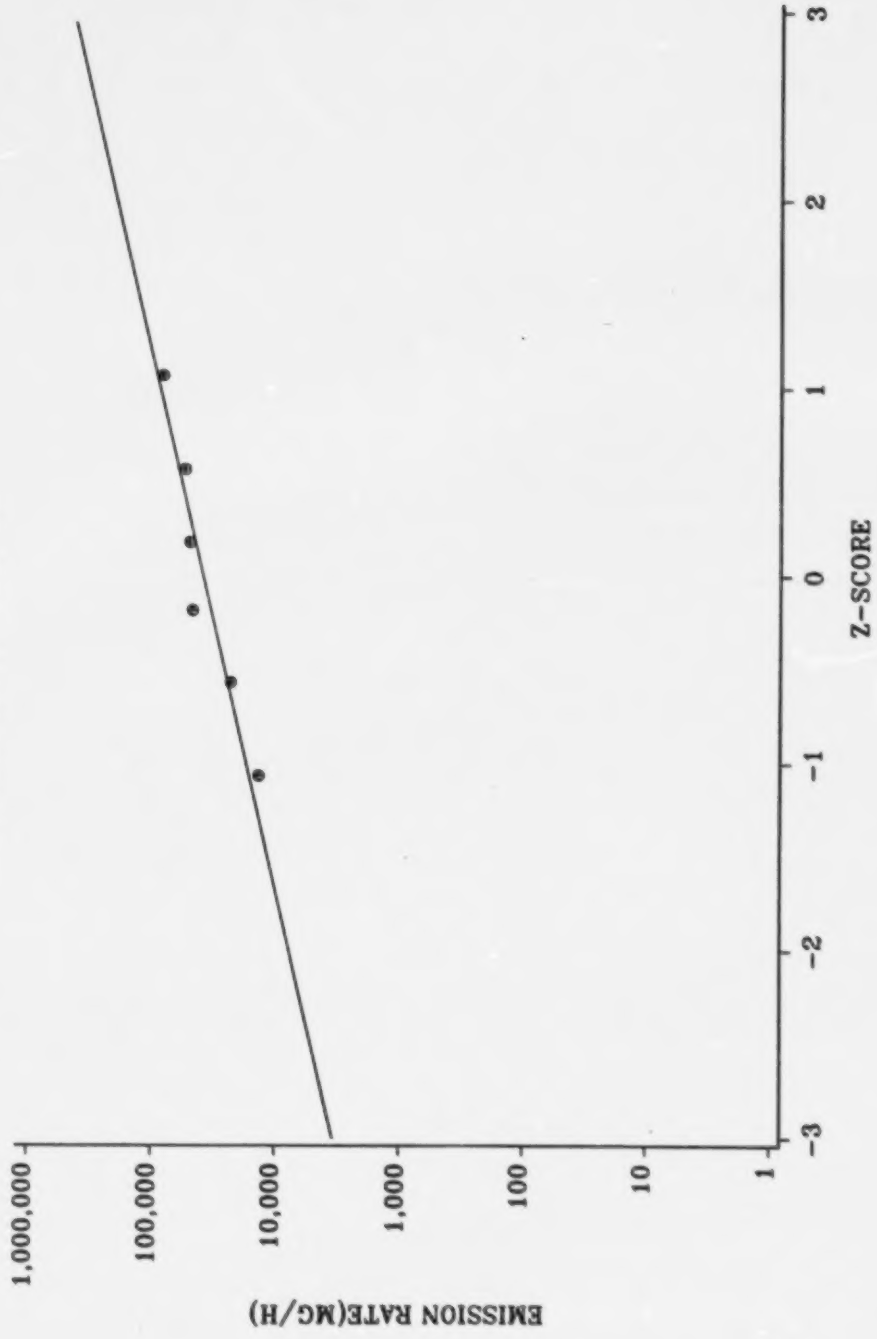

POLLUTANT=SILVER
EMISSION RATE(MG/H)
100,000
10,000
1,000
100
10
1
0.1
0.01
−3
−2
−1
0
1
2
3
Z−SCORE
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=SODIUM



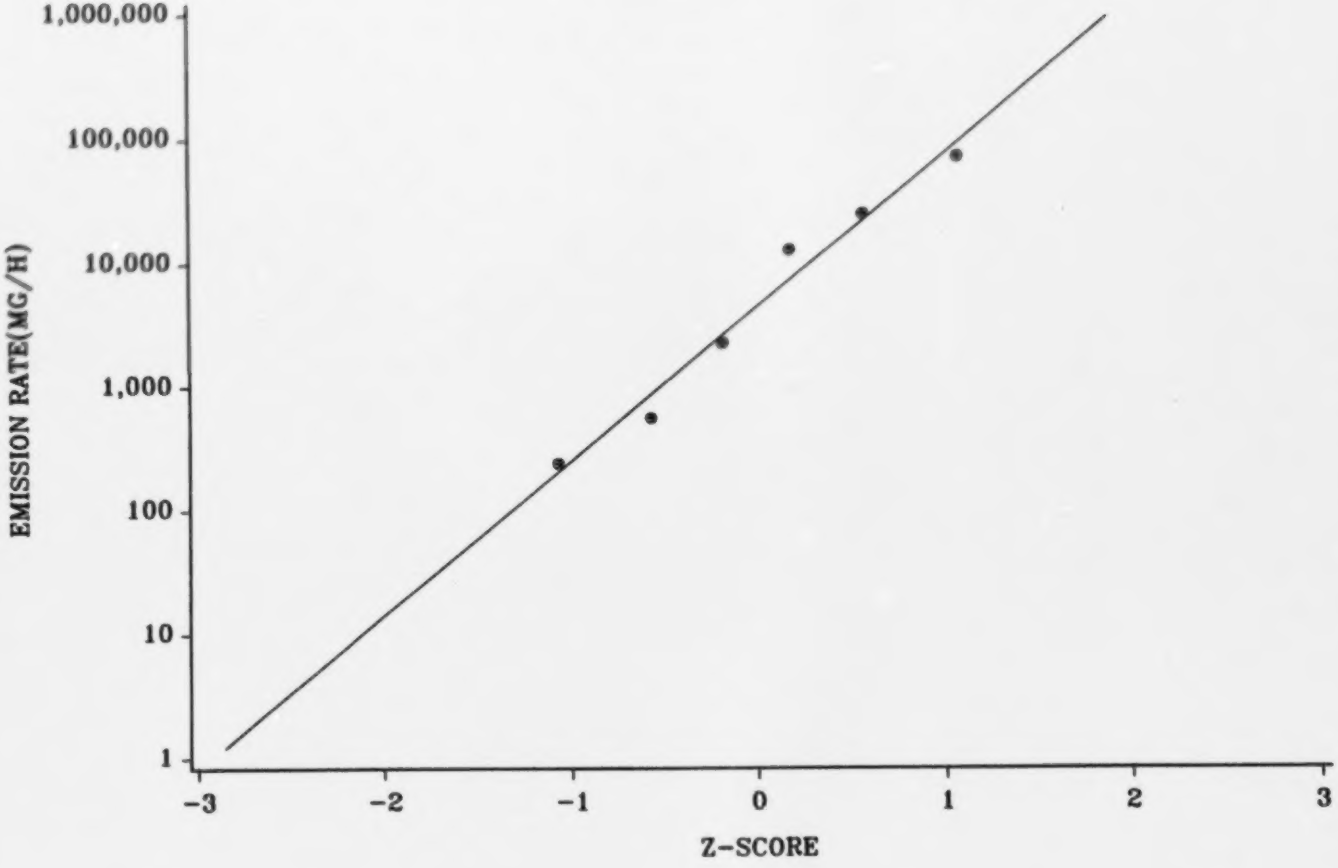
TYPE OF PLOT = LOG-NORMAL PROBABILITY PLOT

POLLUTANT=SULFUR



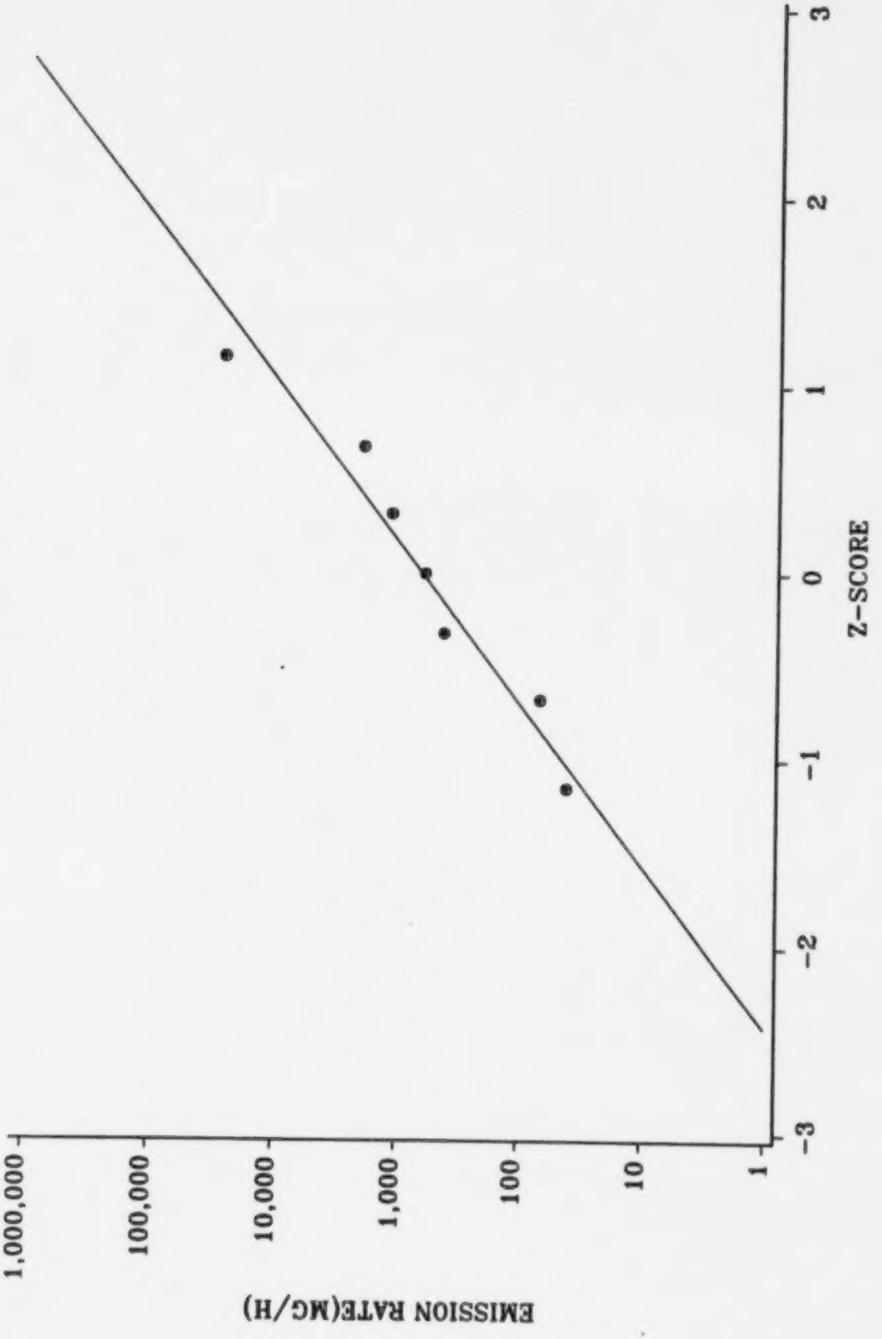
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=TIN



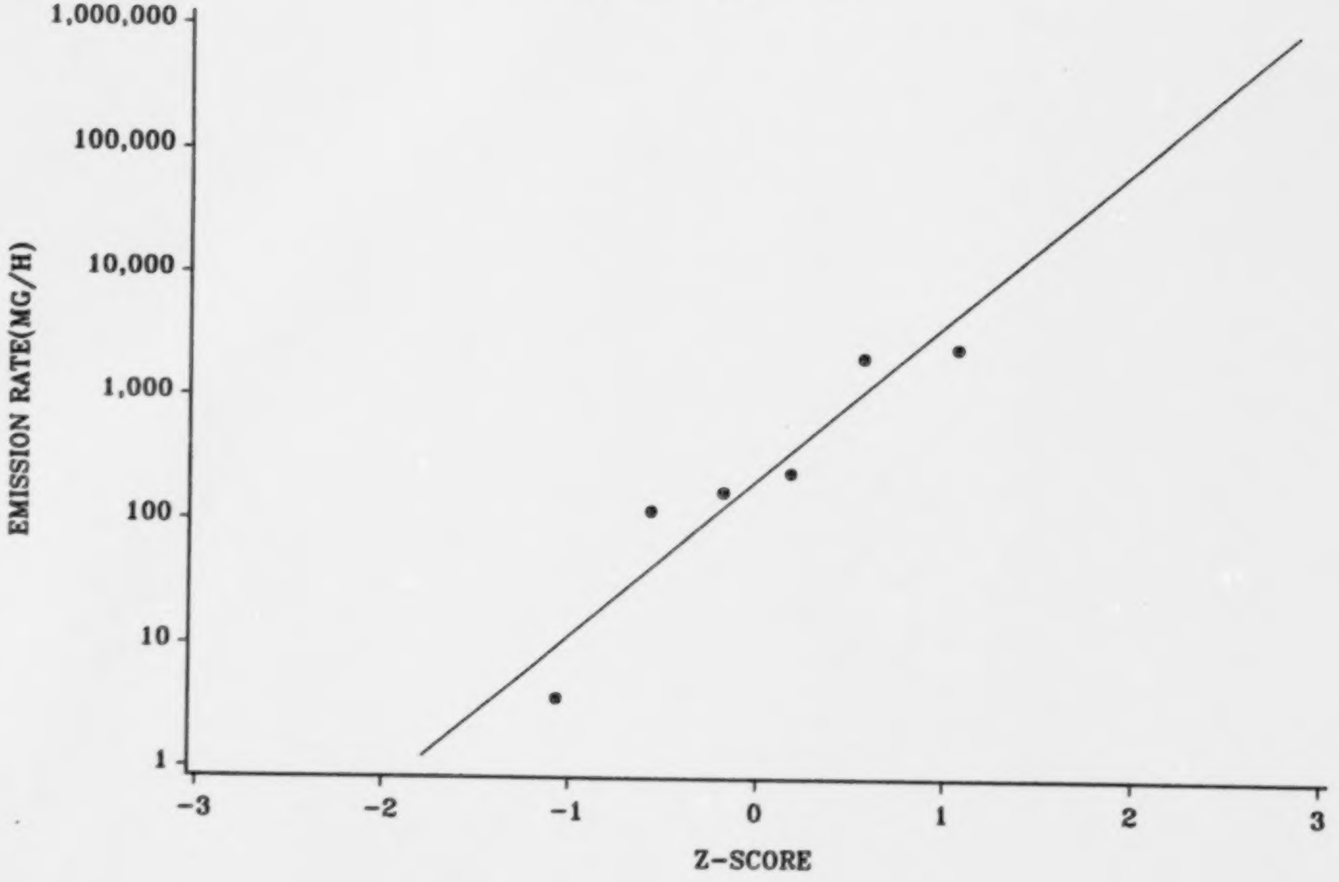
TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=TITANIUM

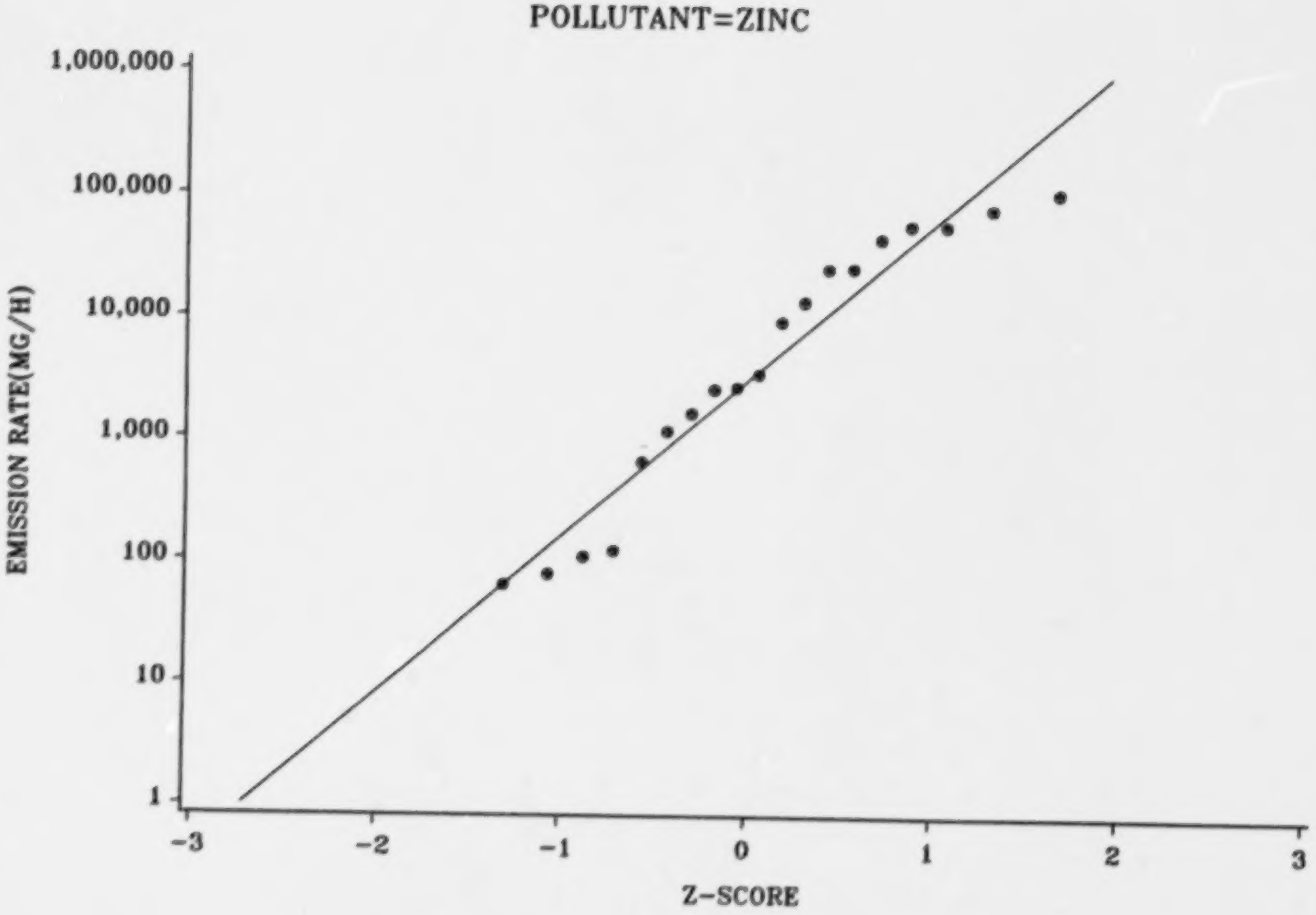


TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

POLLUTANT=VANADIUM



TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT



TYPE OF PLOT = LOG−NORMAL PROBABILITY PLOT

APPENDIX F

Regression Results and Plots of Emission Rates for Metals and Selected Organic Pollutants

MEMORANDUM

DATE: November 1, 1988

SUBJECT: Regression Results and Plots of Emission Rates for Metals and Selected Organic Pollutants

TO: Gene Crumpler
Marla Dombroski
Henry Kahn

FROM: Russ Roegner RR
Bill Yu B.Y.

REFERENCE: EPA Contract No. 68-03-3453, Work Assignment 2-15
SAIC Project No. 1-813-03-295-15

The enclosed is an updated package of the data listings, plots, and SAS regression runs (the base 10 logarithm of % mass emitted on temperature) that you requested from the municipal sludge incineration database. This set of results replaces an earlier version transmitted to you under a memorandum dated October 26, 1988. The revisions were made to clarify the preceding documentation.

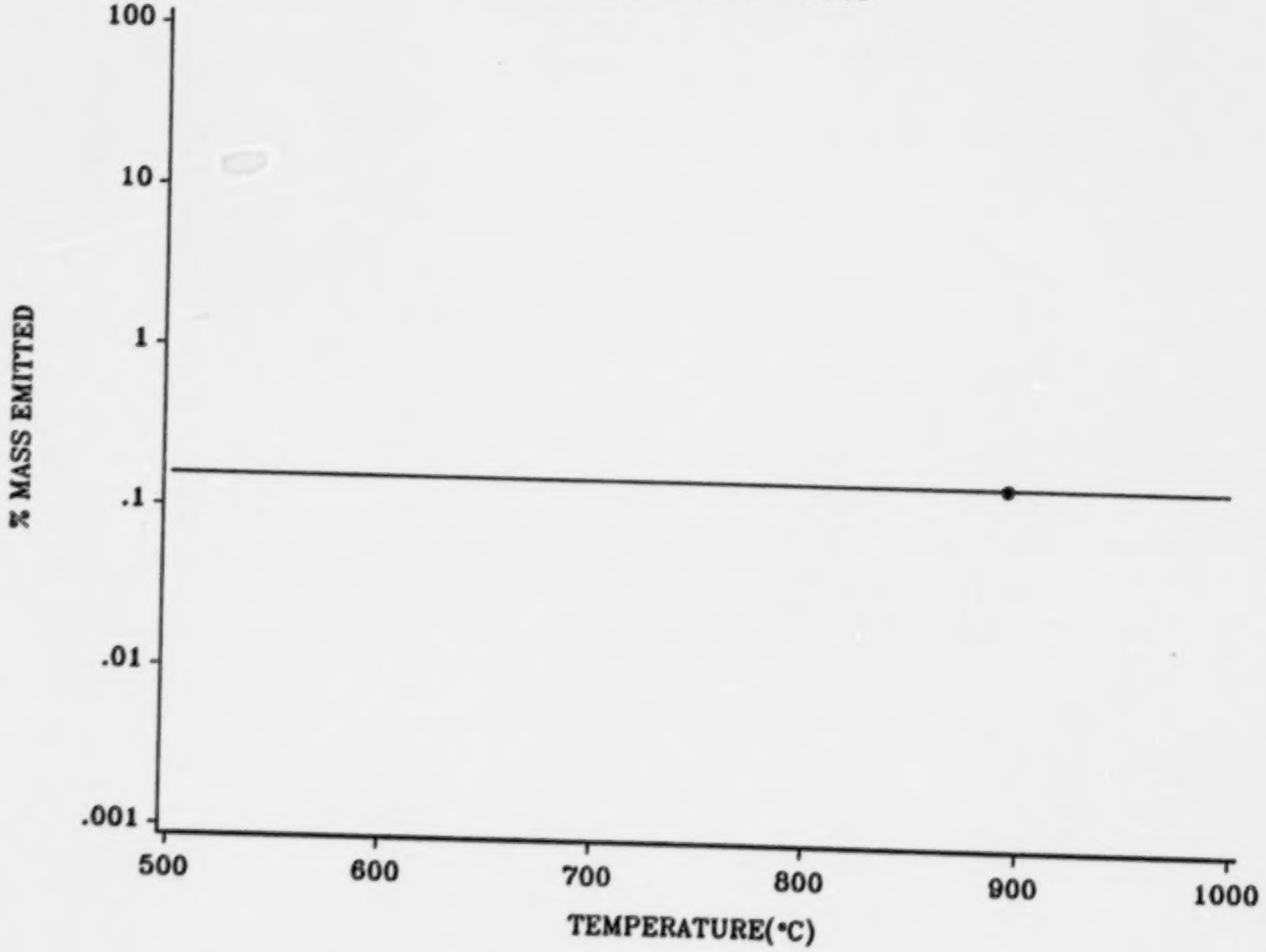
For this set of runs the following editing procedures were implemented:

(1) Only individual observations with emission, feed , and temperature values were used.

(2) If EMISS = ND then EMISS = 0;
% Mass Emitted = (EMISS/FEED)*100;
If % Mass Emitted < 0.001 then % Mass Emitted = 0.001;
If % Mass Emitted > 100 then % Mass Emitted =100.

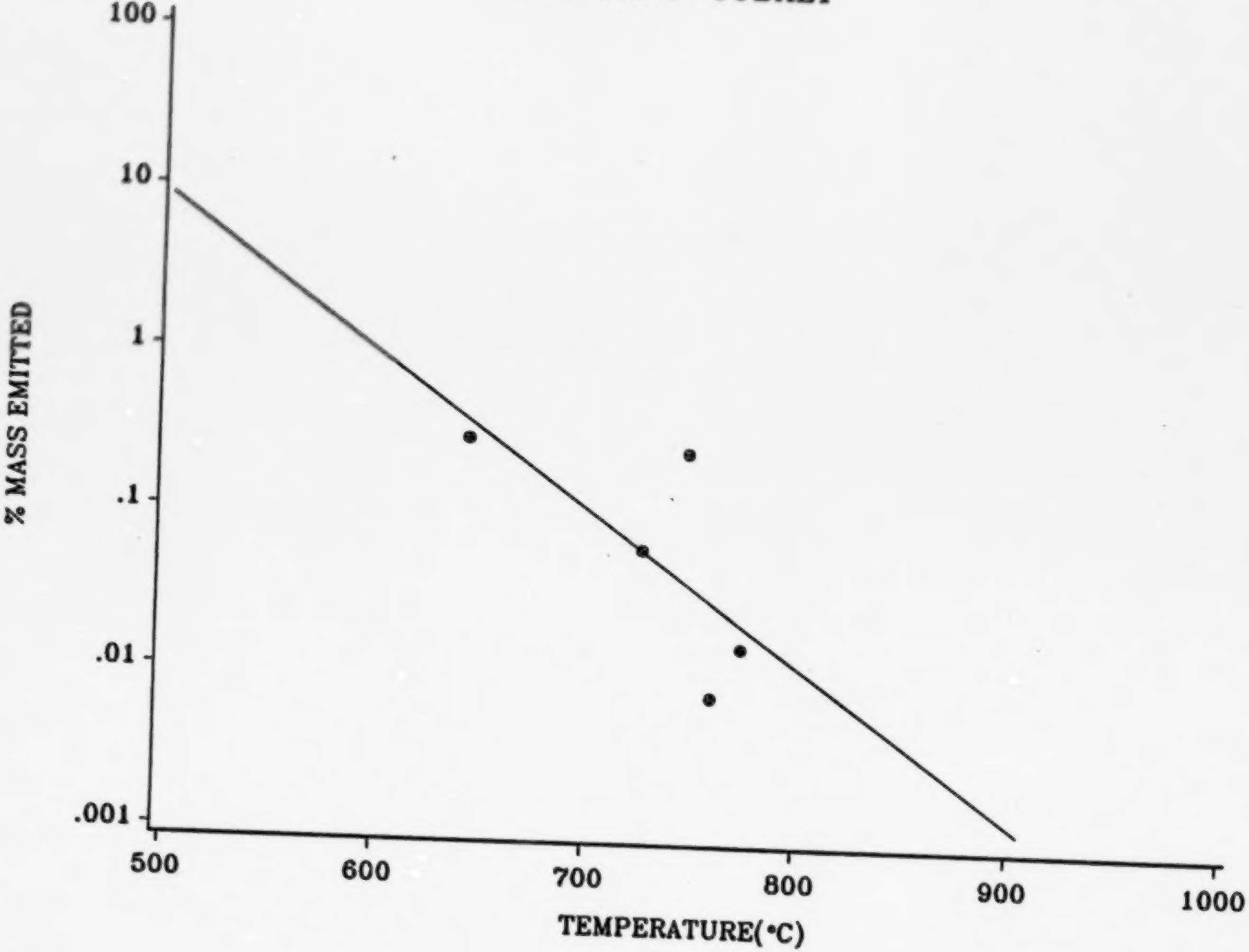
(3) Organics data were taken from incinerators R13, R14, and R15 only.

(4) The following four organic pollutants were selected for plots and regression runs of % mass emitted vs temperature -- benzene, carbon tetrachloride, methylene chloride, and toluene.

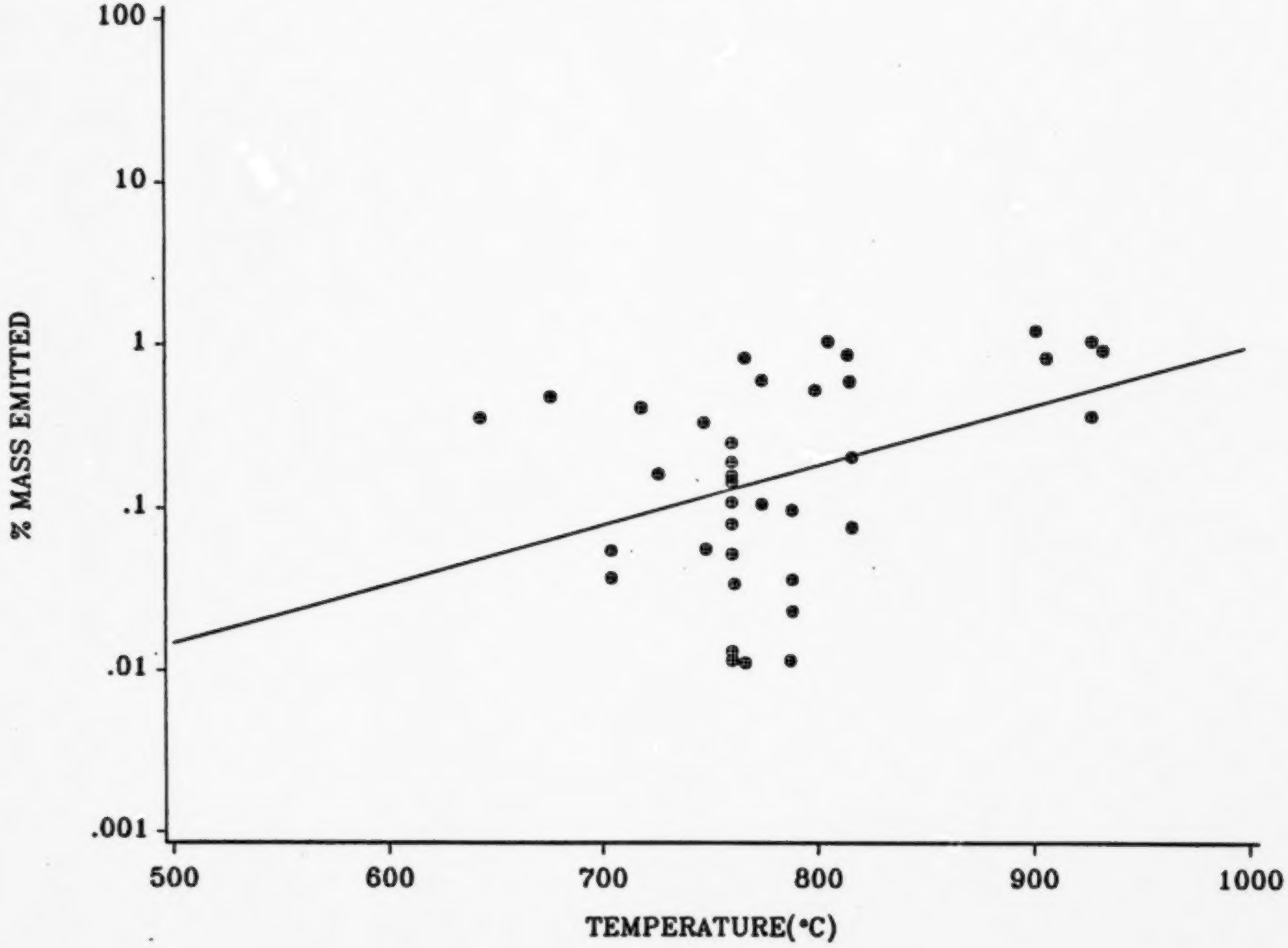


METAL EMISSIONS
POLLUTANT=BERYLLIUM

METAL EMISSIONS
POLLUTANT=COBALT

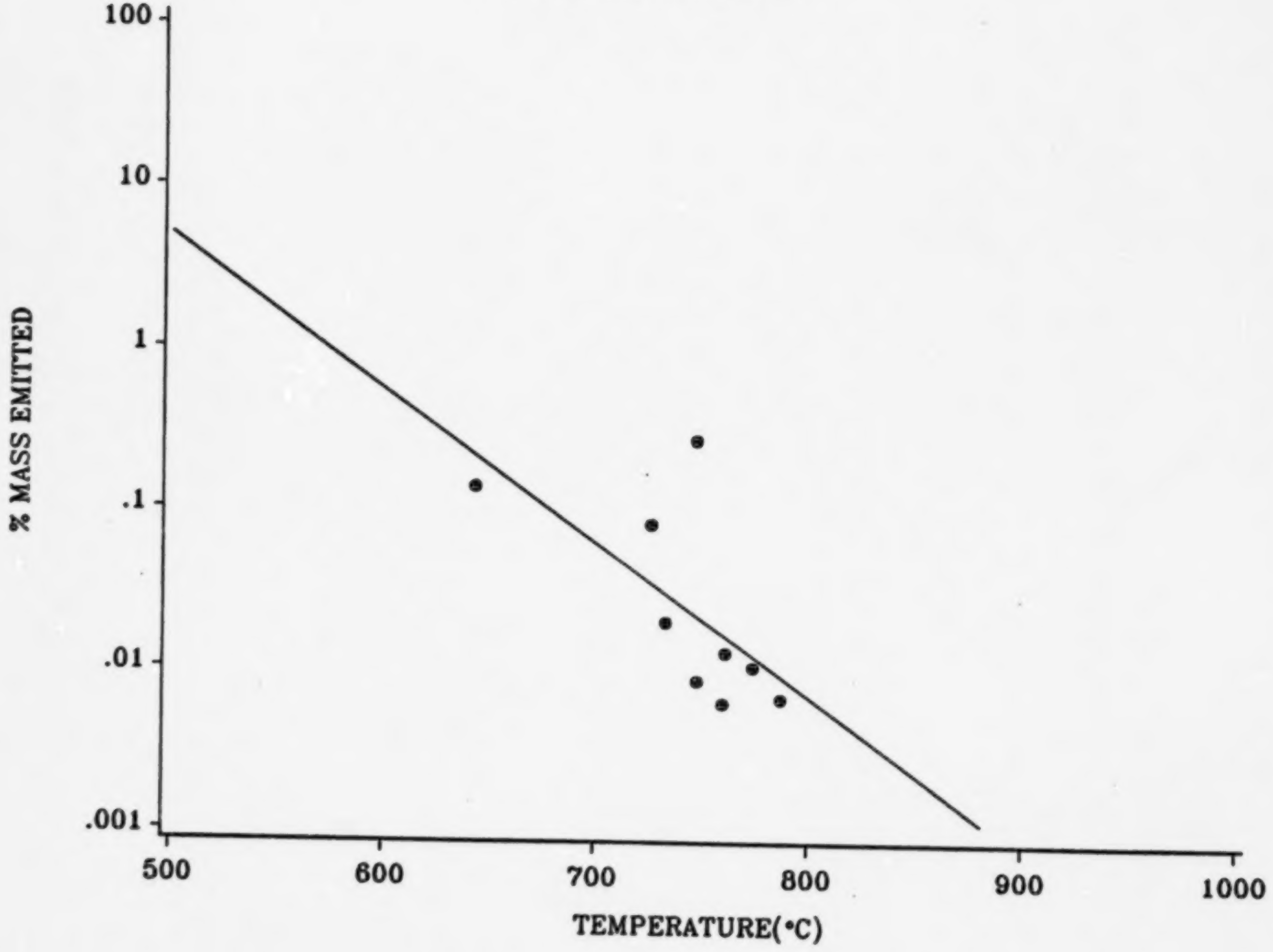


METAL EMISSIONS
POLLUTANT=COPPER



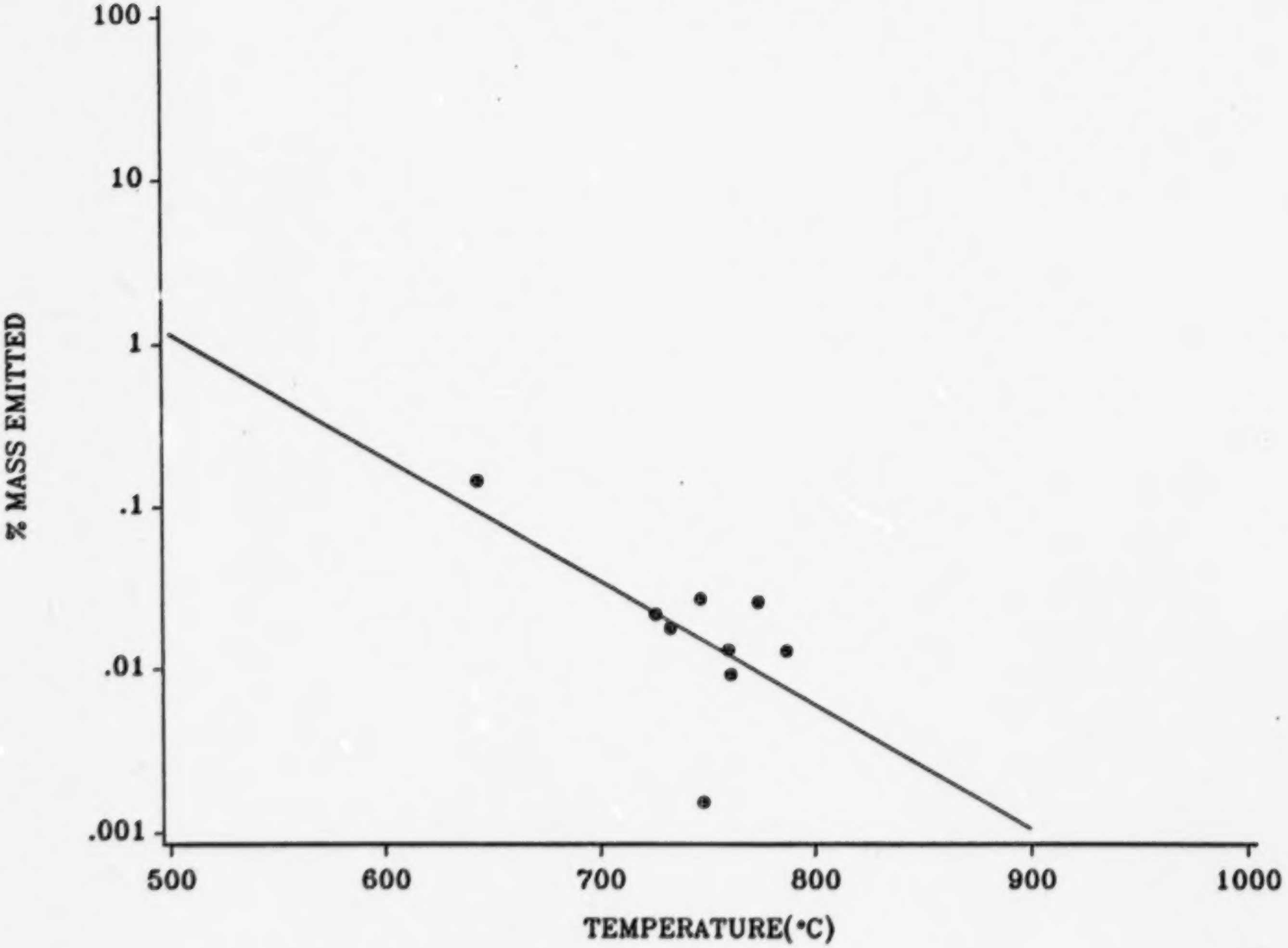
METAL EMISSIONS

POLLUTANT=IRON

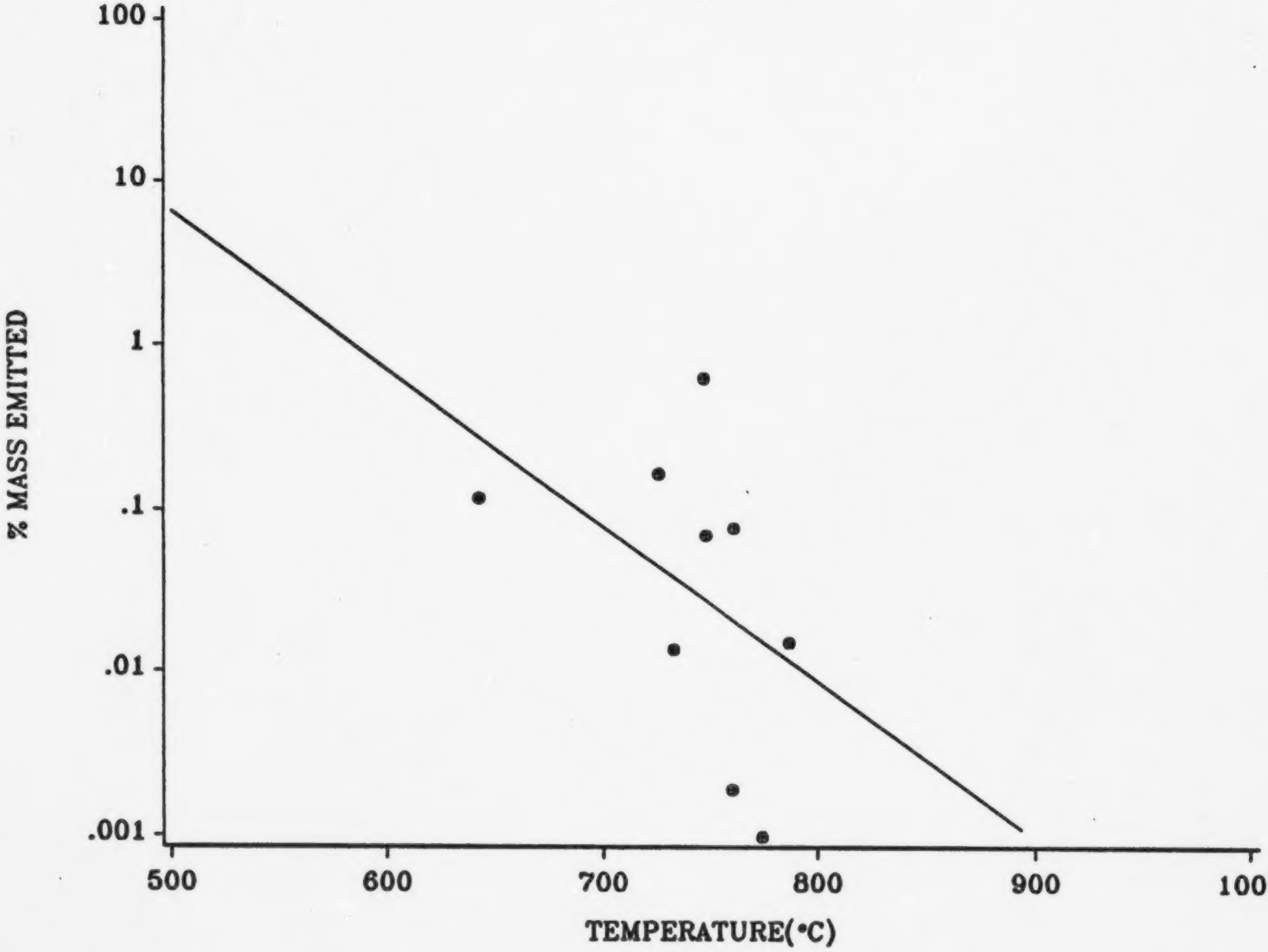


METAL EMISSIONS

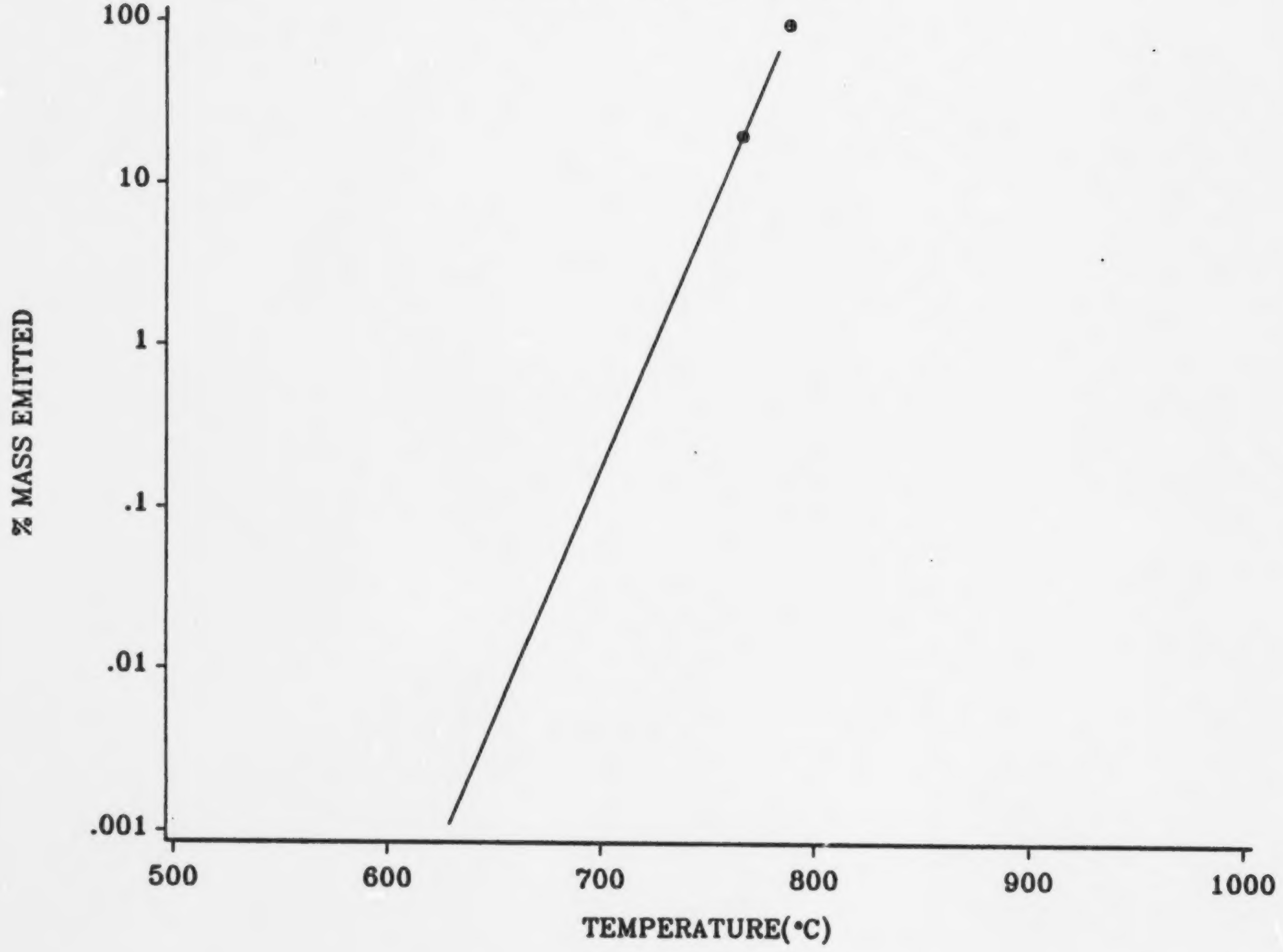
POLLUTANT=MAGNESIUM

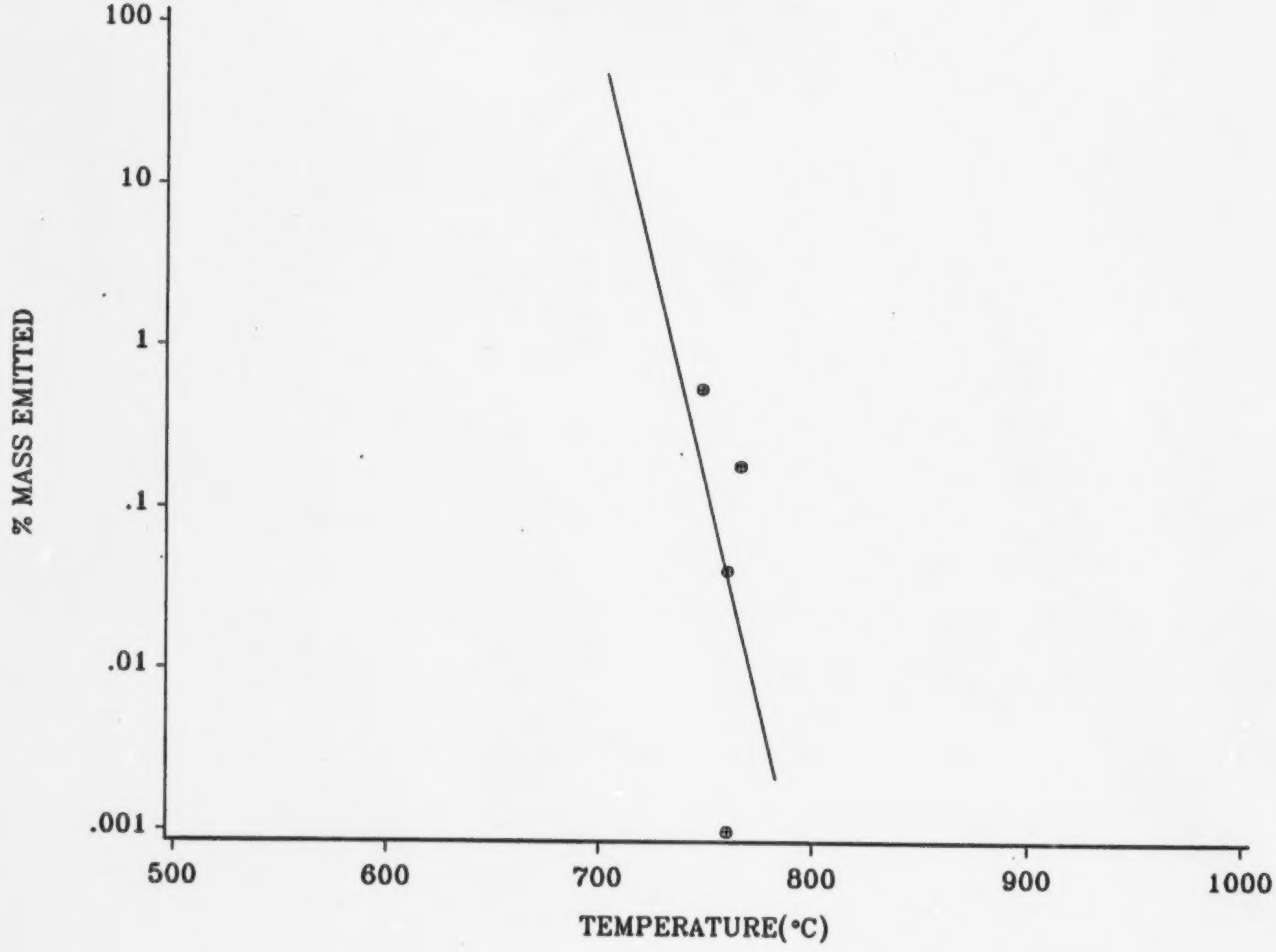


METAL EMISSIONS
POLLUTANT=MANGANESE



METAL EMISSIONS
POLLUTANT=MERCURY

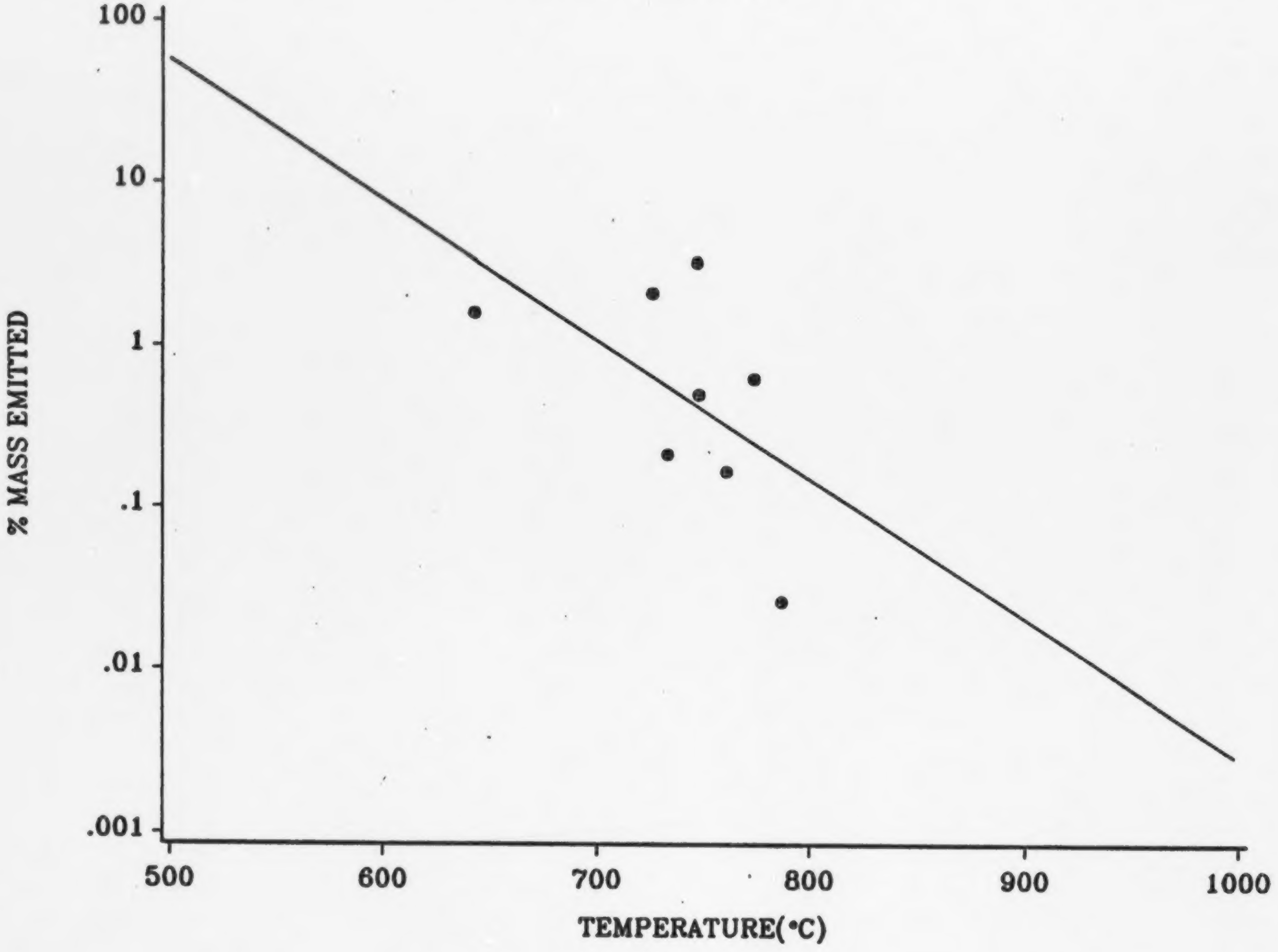




METAL EMISSIONS
POLLUTANT=SILVER

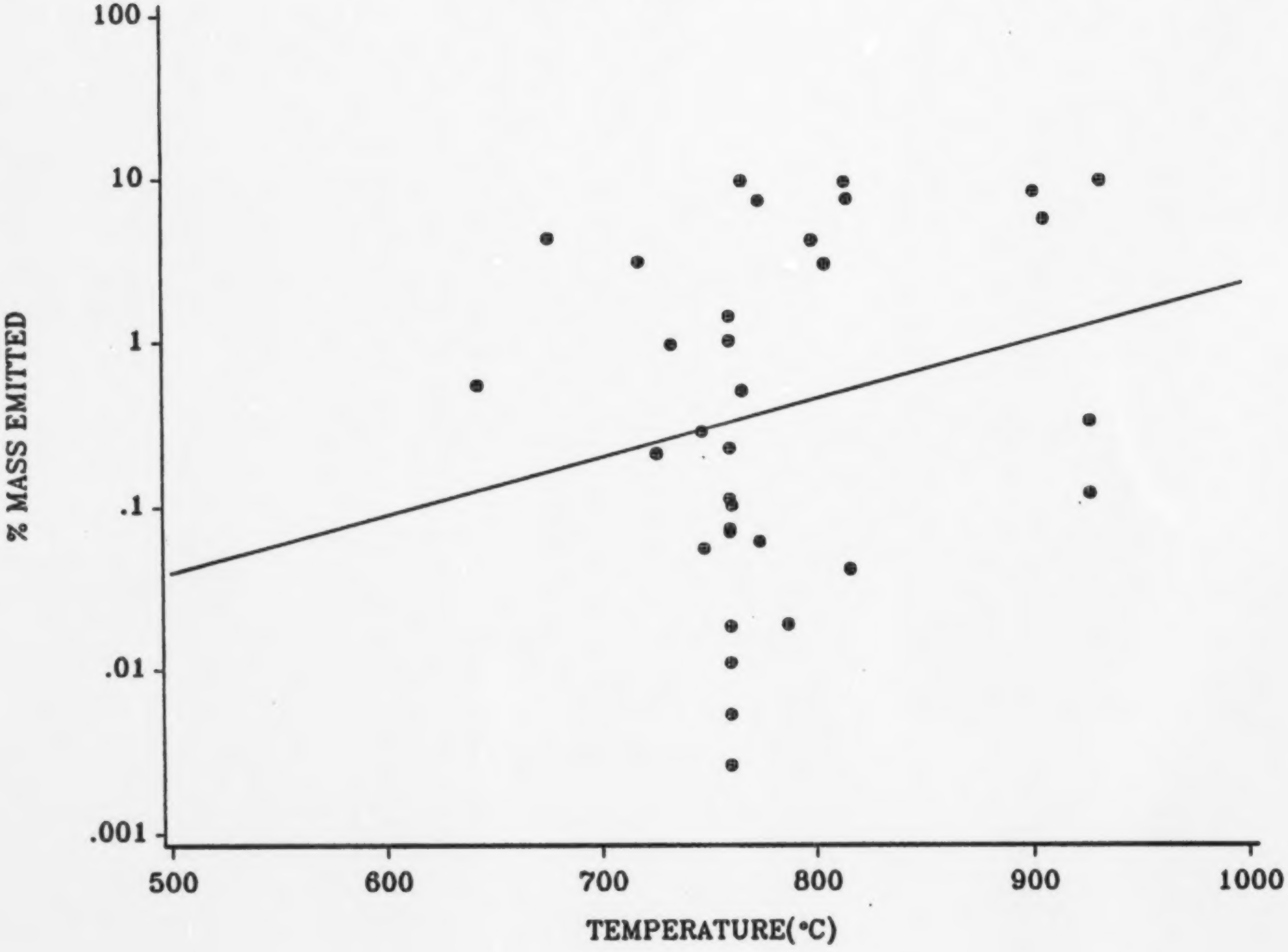
F-9-

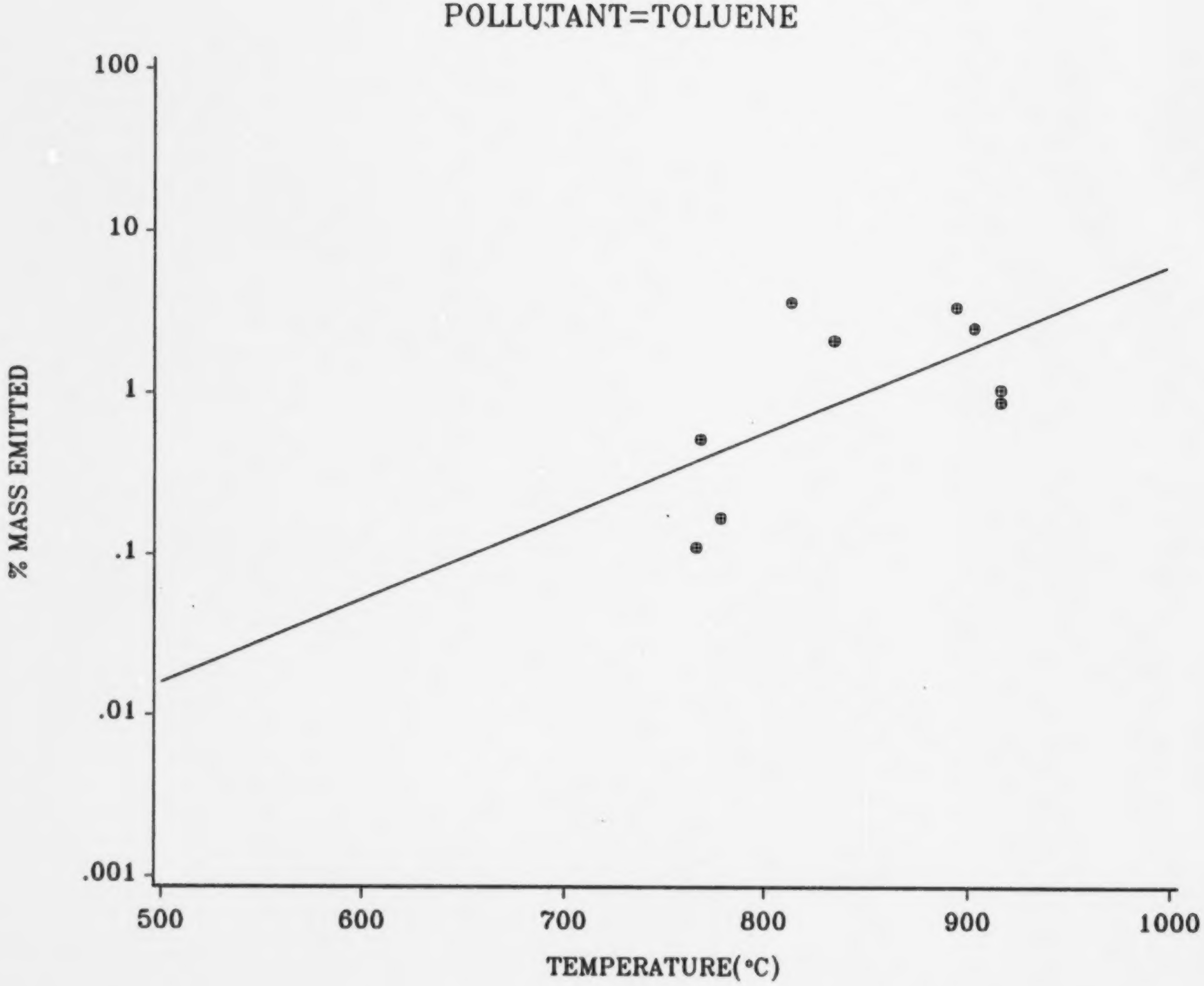
METAL EMISSIONS
POLLUTANT=TIN

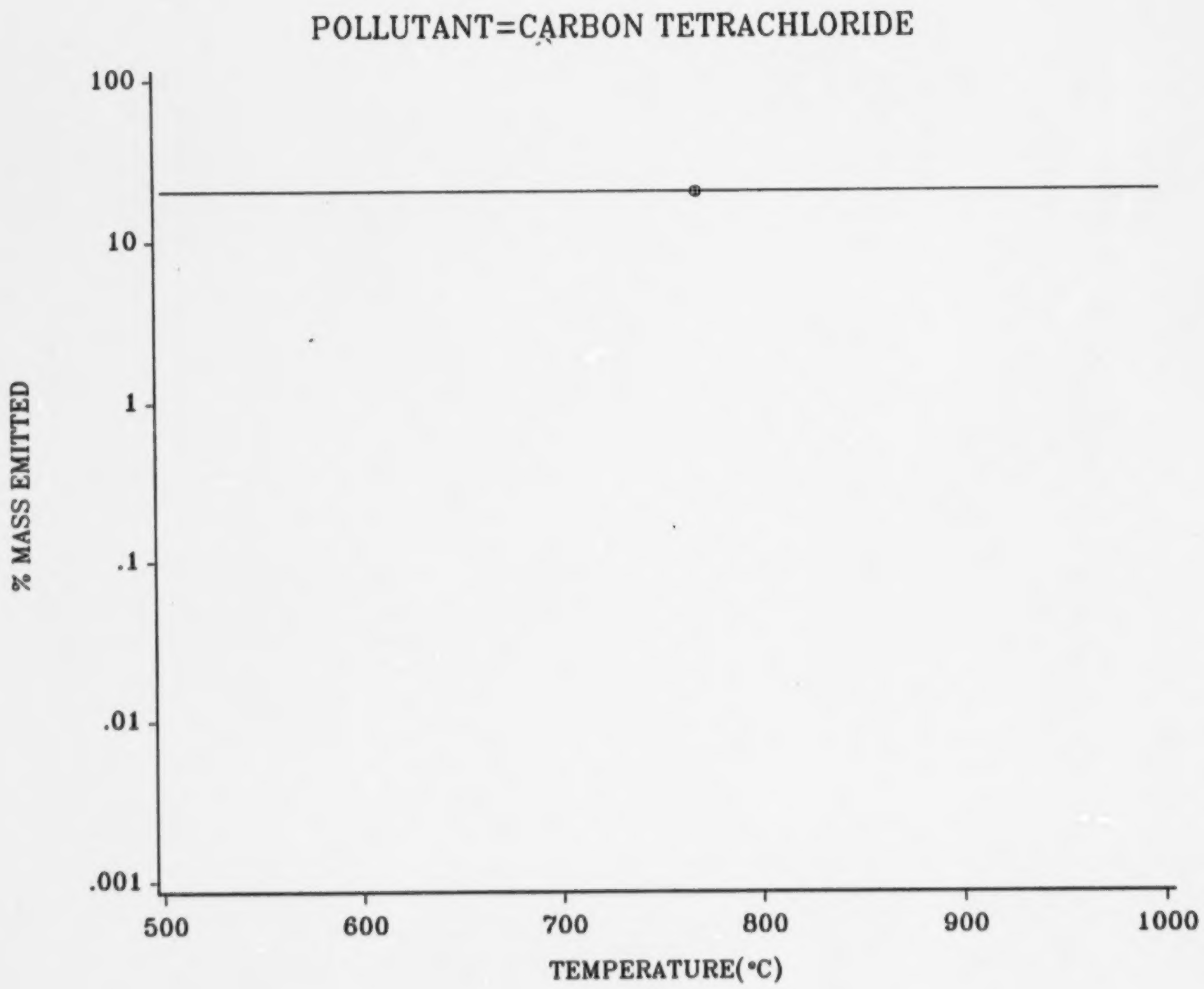


METAL EMISSIONS

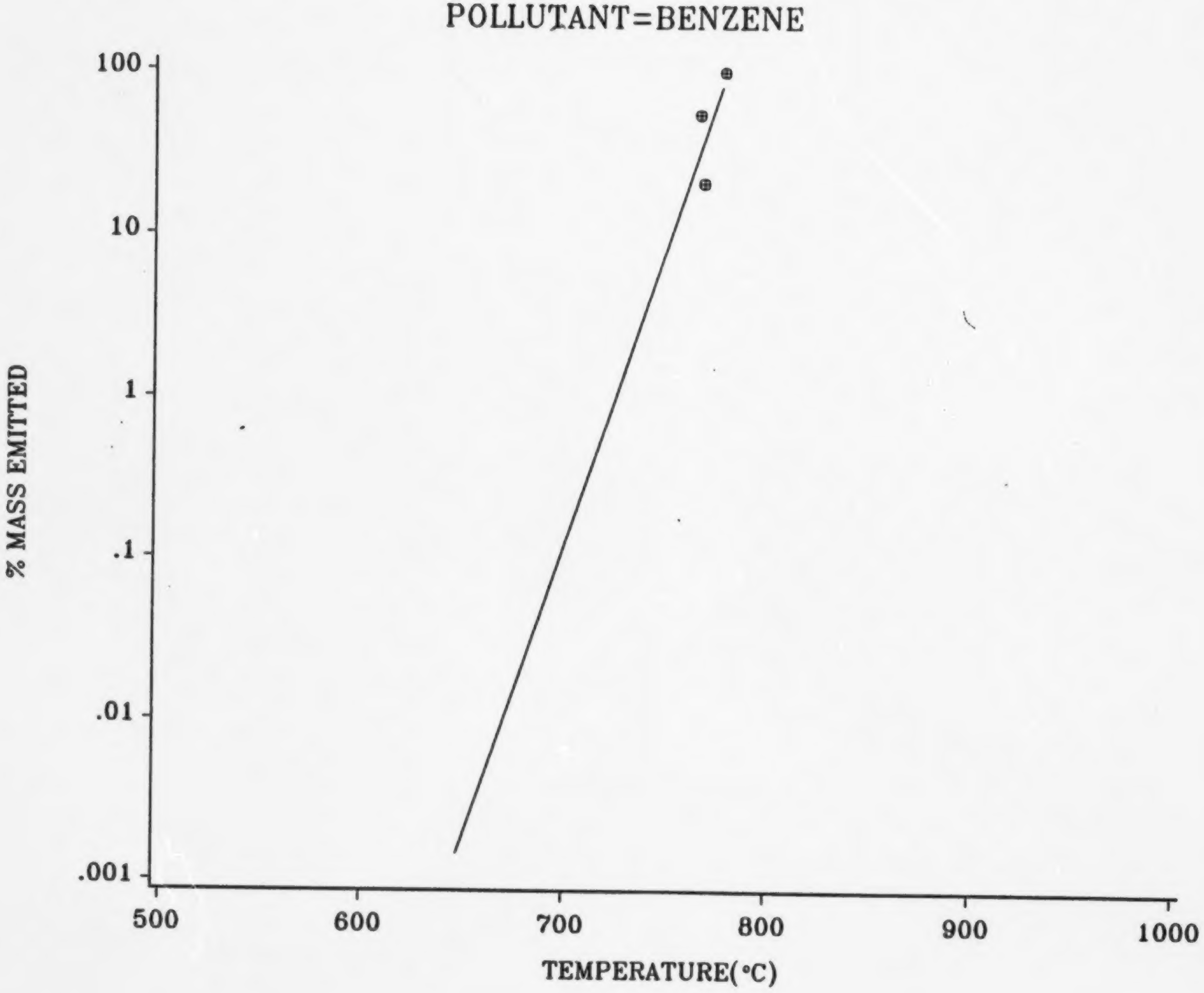
POLLUTANT=ZINC

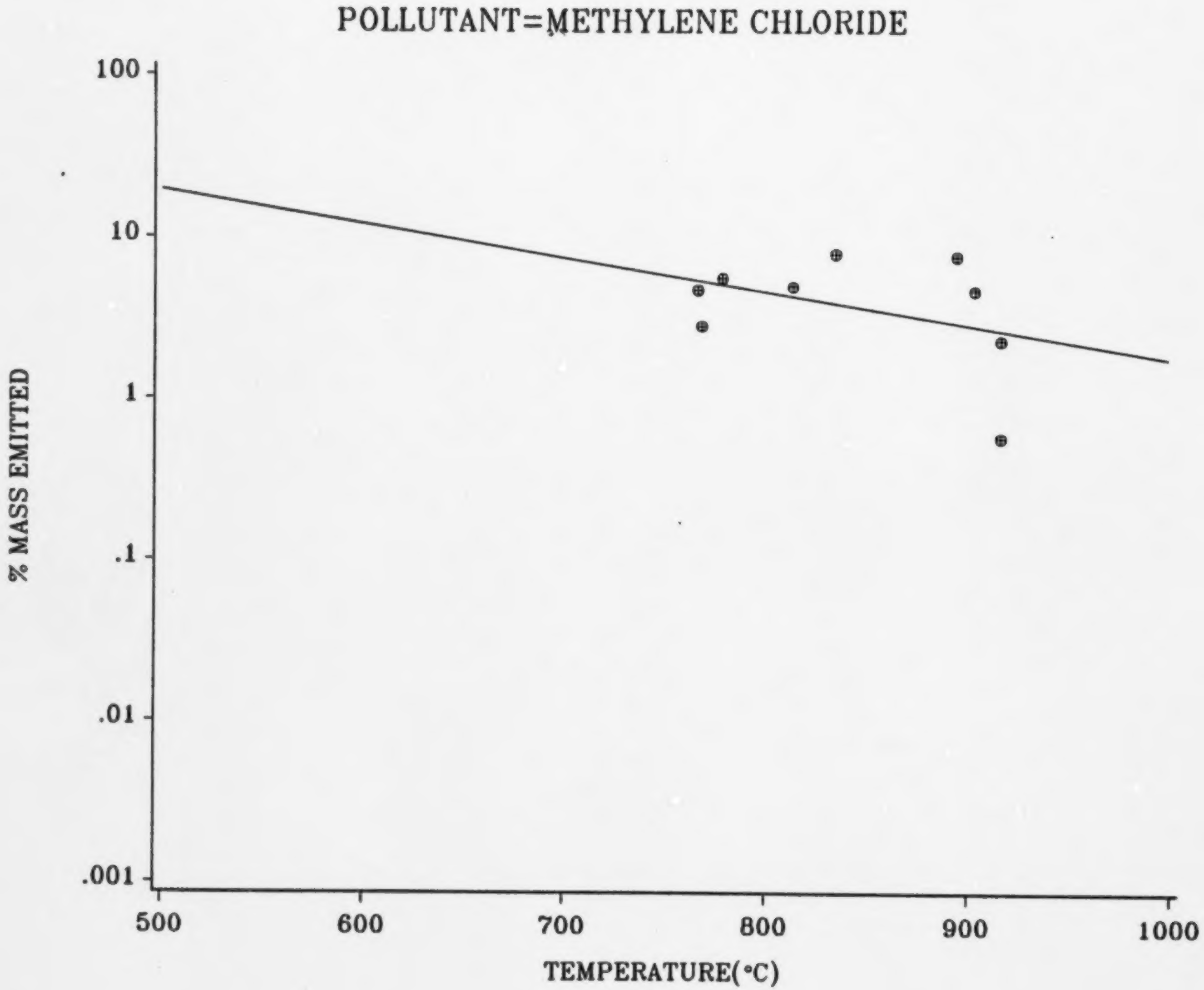



POLLUTANT=TOLUENE
100
10
1
.1
.01
.001
% MASS EMITTED
500
600
700
800
900
1000
TEMPERATURE(°C)



POLLUTANT=CARBON TETRACHLORIDE

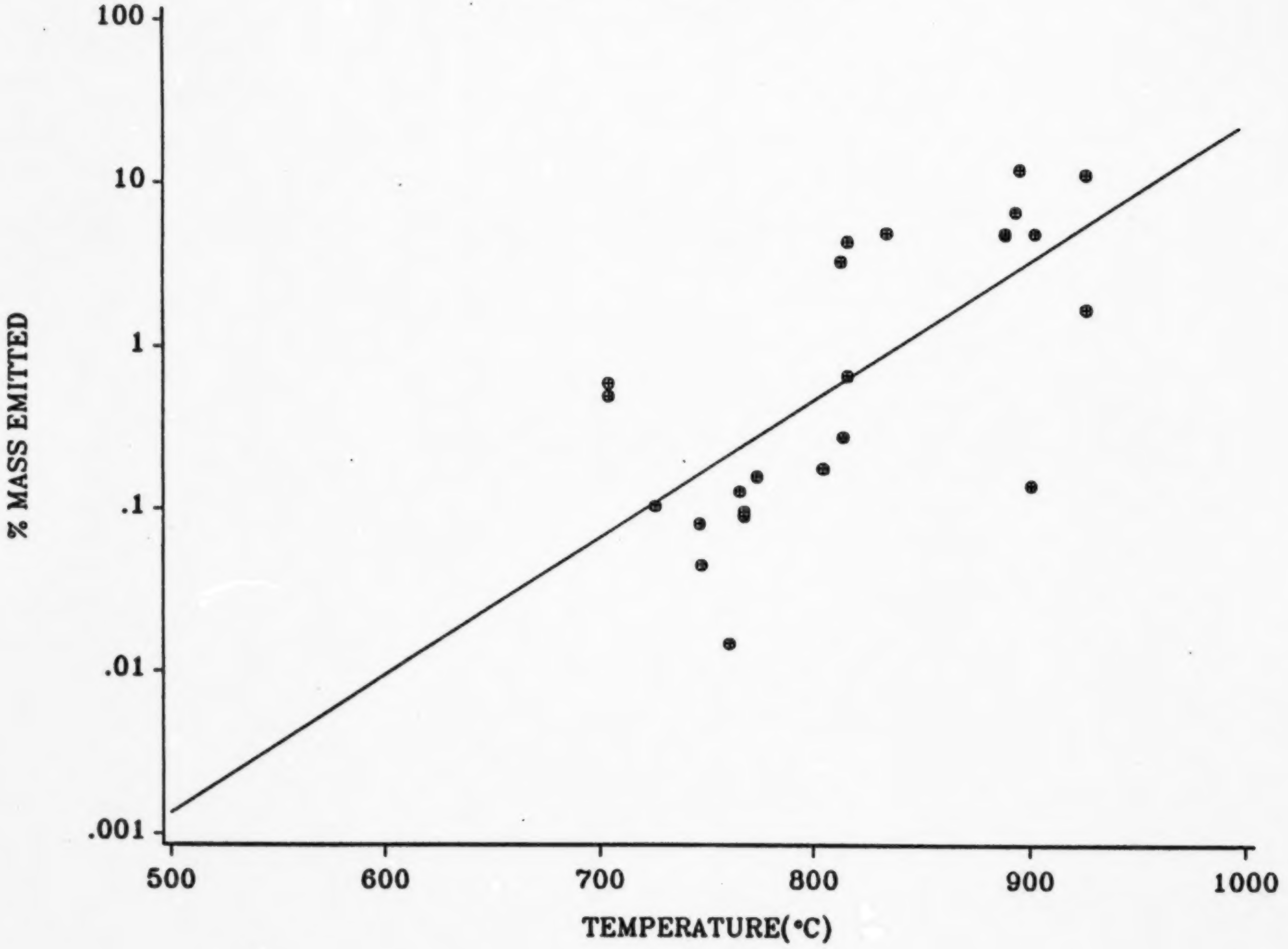

POLLUTANT=BENZENE
% MASS EMITTED
100
10
1
.1
.01
.001
500
600
700
800
900
1000
TEMPERATURE(°C)


POLLUTANT=METHYLENE CHLORIDE
% MASS EMITTED
100
10
1
.1
.01
.001
500
600
700
800
900
1000
TEMPERATURE(°C)

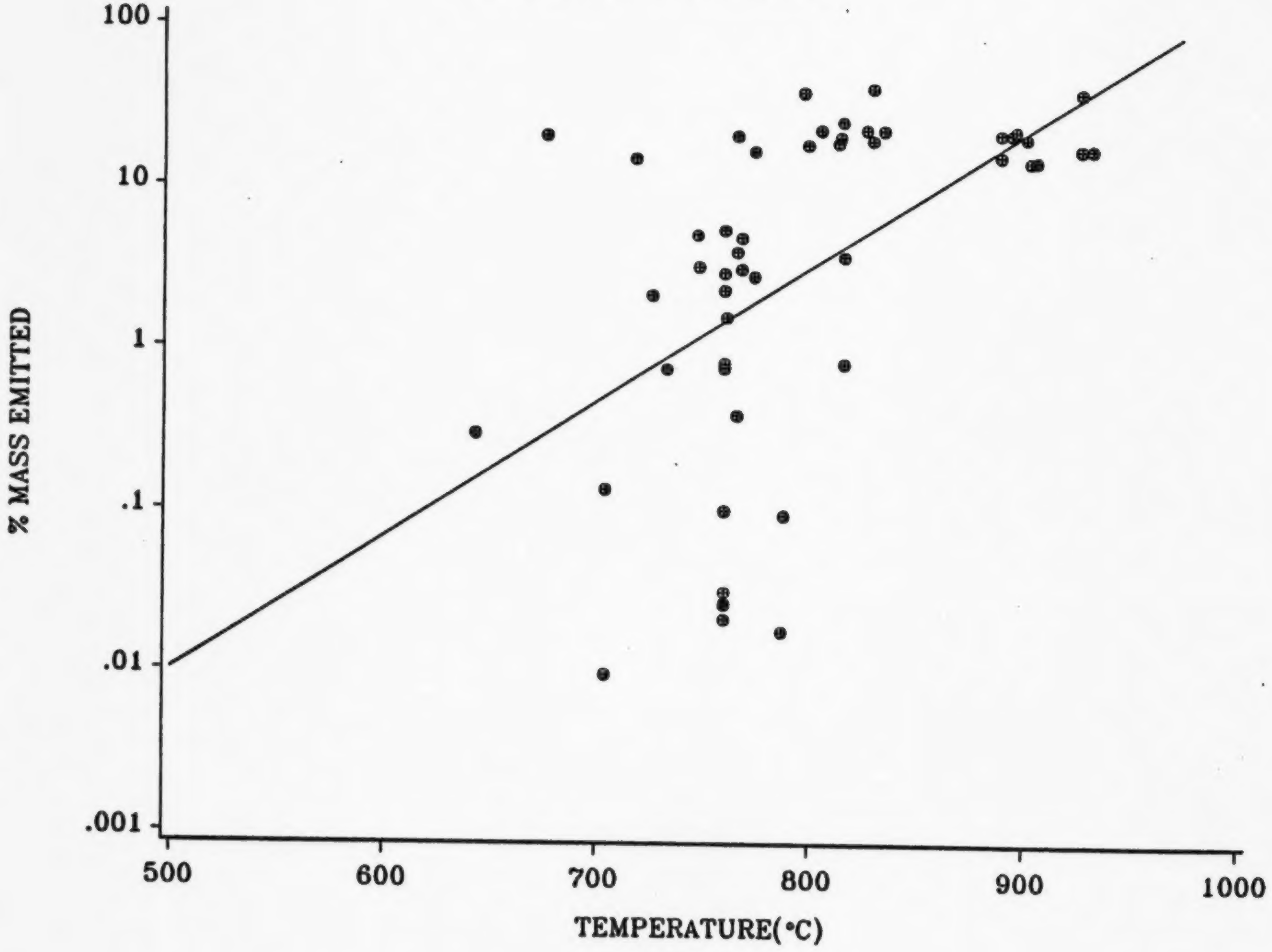
```
------------------------------------ BENZENE ---------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                             Analysis of Variance

                                Sum of         Mean
       Source          DF      Squares       Square      F Value       Prob>F

       Model            1      0.11140      0.11140        0.890       0.5185
       Error            1      0.12517      0.12517
       C Total          2      0.23657

           Root MSE       0.35379     R-square       0.4709
           Dep Mean       1.68587     Adj R-sq      -0.0582
           C.V.          20.98585

                             Parameter Estimates

                      Parameter      Standard    T for H0:
     Variable   DF     Estimate         Error   Parameter=0    Prob > |T|

     INTERCEP    1   -26.604636   29.98896409        -0.887        0.5380
     TEMPERATURE 1     0.036709    0.03891211         0.943        0.5185


----------------------------- CARBON TETRACHLORIDE ----------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                             Analysis of Variance

                                Sum of         Mean
       Source          DF      Squares       Square      F Value       Prob>F

       Model            0      0.00000       .              .           .
       Error            0      0.00000       .
       C Total          0      0.00000

           Root MSE        .          R-square       .
           Dep Mean       1.31490     Adj R-sq       .
           C.V.            .

NOTE: Model is not full rank. Least-squares solutions for the parameters are
      not unique. Some statistics will be misleading. A reported DF of 0 or B
      means that the estimate is biased.
      The following parameters have been set to 0, since the variables are a
      linear combination of other variables as shown.

       TEMP     = +768.0000 * INTERCEP
                             Parameter Estimates

                      Parameter      Standard    T for H0:
     Variable   DF     Estimate         Error   Parameter=0    Prob > |T|

     INTERCEP    B     1.314898     .                  .            .
     TEMPERATURE 0            0     .                  .            .
```

```
------------------------------ METHYLENE CHLORIDE ---------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                          Analysis of Variance

                              Sum of         Mean
      Source          DF     Squares       Square      F Value       Prob>F

      Model            1     0.14571      0.14571        1.204       0.3088
      Error            7     0.84718      0.12103
      C Total          8     0.99289

          Root MSE       0.34789     R-square       0.1468
          Dep Mean       0.57644     Adj R-sq       0.0249
          C.V.          60.35120

                          Parameter Estimates

                      Parameter       Standard    T for H0:
    Variable    DF     Estimate          Error   Parameter=0    Prob > |T|

    INTERCEP     1     2.331711     1.60387157         1.454        0.1893
    TEMPERATURE 1     -0.002082     0.00189735        -1.097        0.3088


------------------------------------ TOLUENE ---------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                          Analysis of Variance

                              Sum of         Mean
      Source          DF     Squares       Square      F Value       Prob>F

      Model            1     0.89983      0.89983        4.078       0.0832
      Error            7     1.54451      0.22064
      C Total          8     2.44434

          Root MSE       0.46973     R-square       0.3681
          Dep Mean      -0.02082     Adj R-sq       0.2779
          C.V.       -2256.41639

                          Parameter Estimates

                      Parameter       Standard    T for H0:
    Variable    DF     Estimate          Error   Parameter=0    Prob > |T|

    INTERCEP     1    -4.382702     2.16559556        -2.024        0.0827
    TEMPERATURE 1      0.005174     0.00256185         2.019        0.0832
```

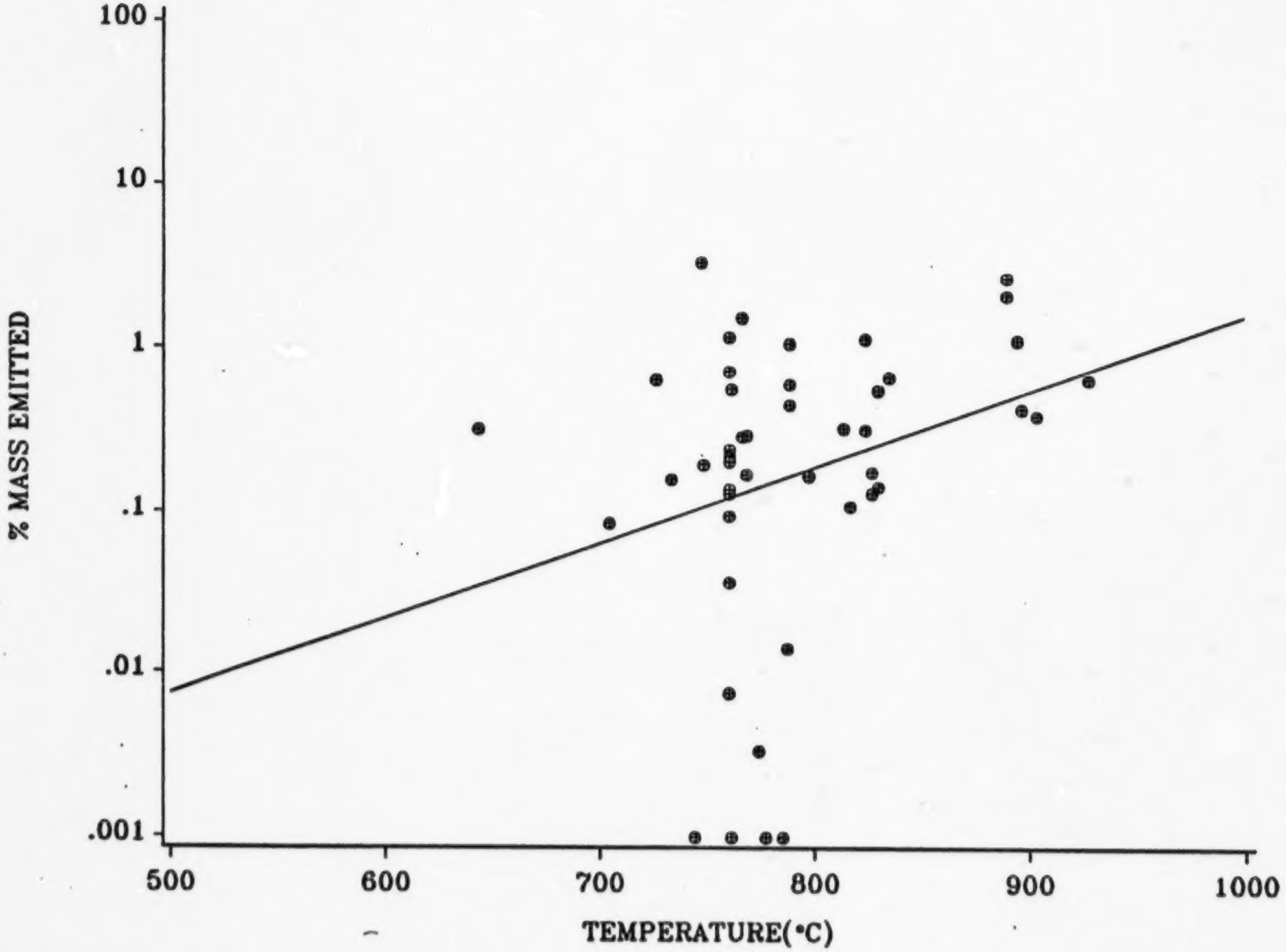
METAL EMISSIONS
POLLUTANT=ARSENIC



METAL EMISSIONS
POLLUTANT=CADMIUM

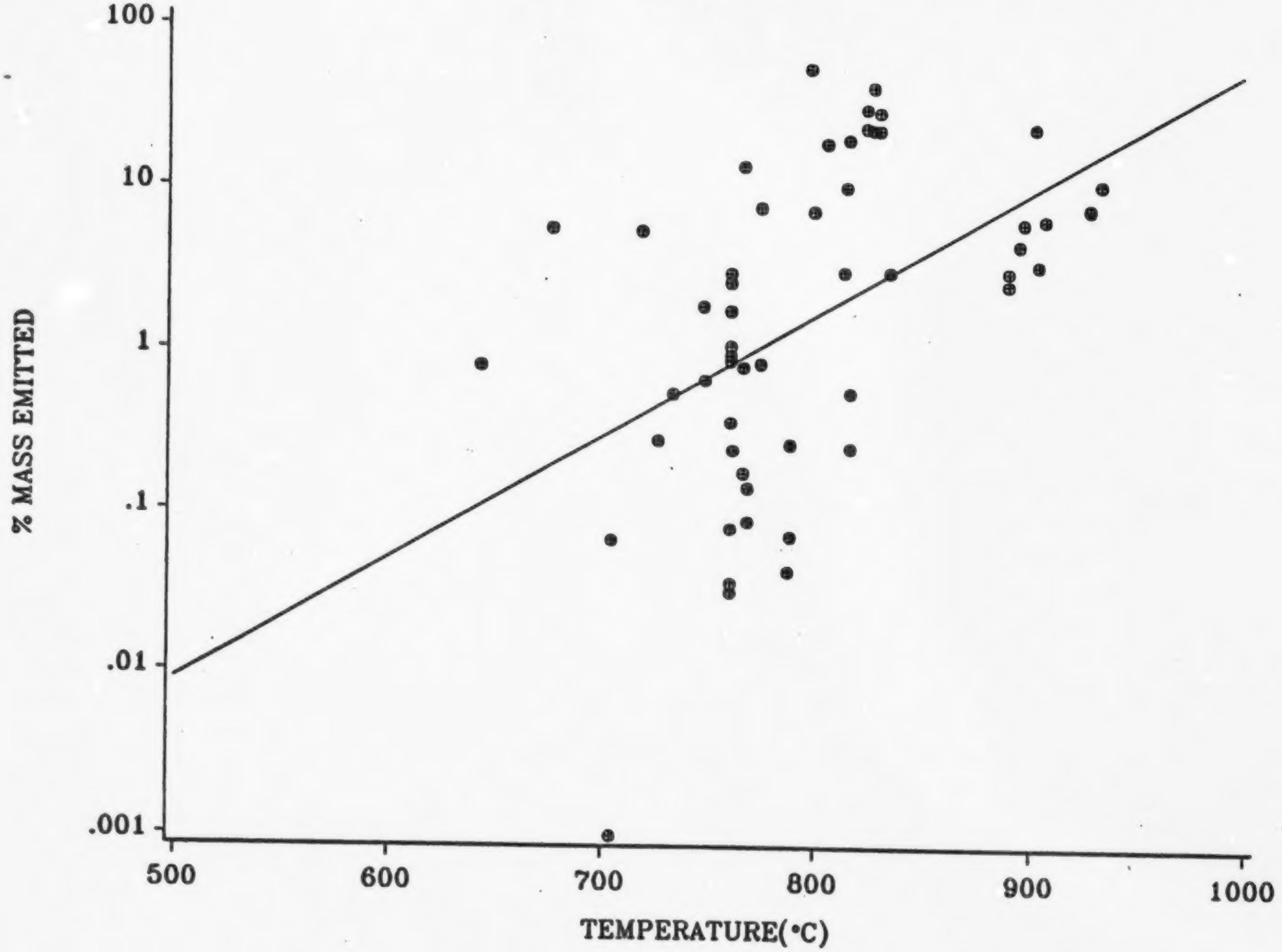


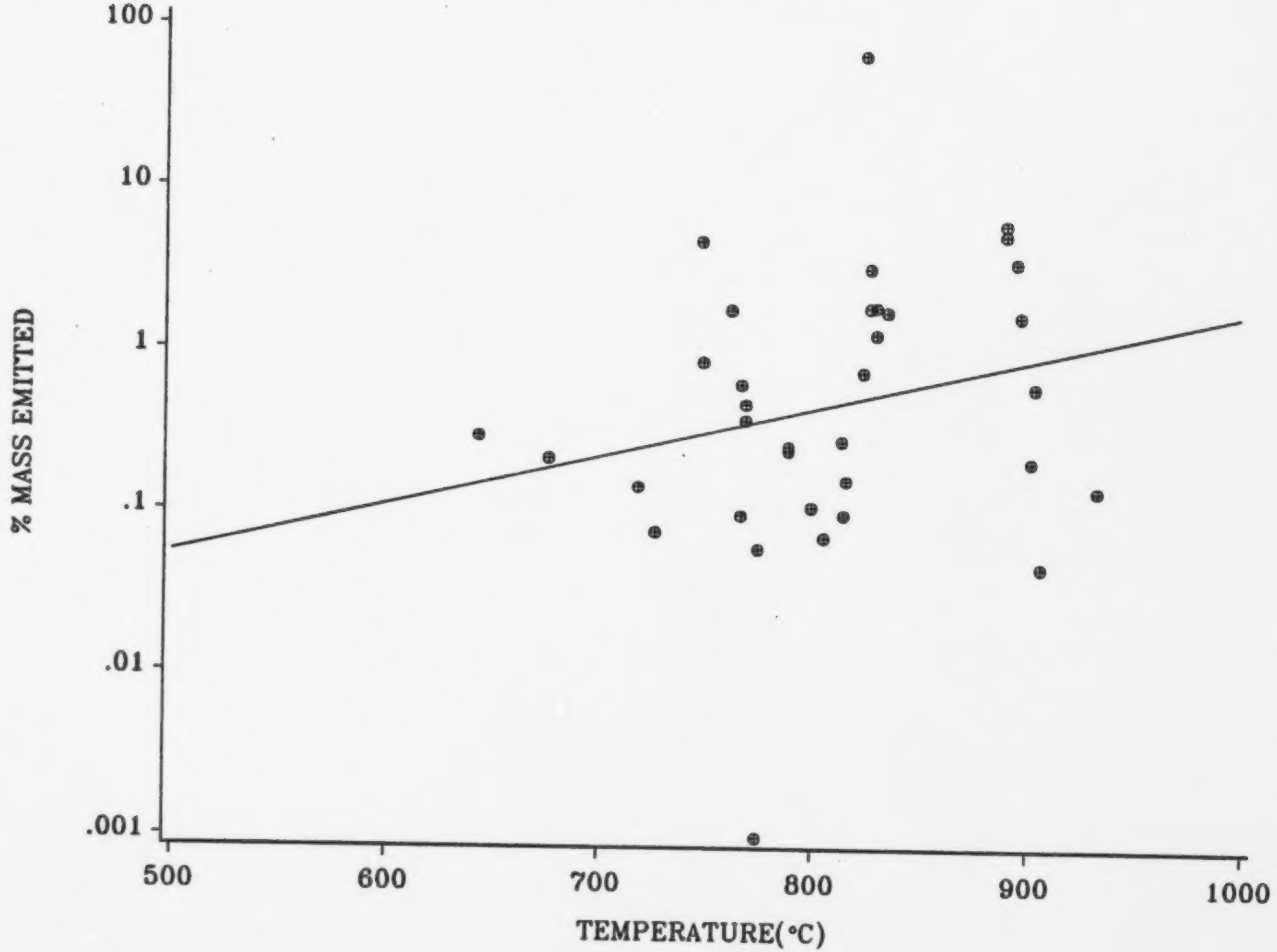
METAL EMISSIONS
POLLUTANT=CHROMIUM



METAL EMISSIONS

POLLUTANT=LEAD





METAL EMISSIONS
POLLUTANT=NICKEL

```
                                 SAS     10:58 Wednesday, October 26, 1988
                                                                         1

----------------------------------- ARSENIC ------------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                              Analysis of Variance

                                 Sum of         Mean
      Source          DF        Squares       Square      F Value       Prob>F

      Model            1        8.44587      8.44587       20.861       0.0002
      Error           22        8.90683      0.40486
      C Total         23       17.35269

          Root MSE       0.63628     R-square       0.4867
          Dep Mean      -0.18923     Adj R-sq       0.4634
          C.V.        -336.24809

                              Parameter Estimates

                     Parameter      Standard    T for H0:
    Variable    DF    Estimate         Error   Parameter=0    Prob > |T|

    INTERCEP     1   -7.109421    1.52067334        -4.675        0.0001
    TEMPERATURE 1     0.008478    0.00185619         4.567        0.0002
```

Kenston [illegible]

```
                                                                         2

---------------------------------- BERYLLIUM -----------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                              Analysis of Variance

                                 Sum of         Mean
      Source          DF        Squares       Square      F Value       Prob>F

      Model            0        0.00000            .            .            .
      Error            0        0.00000            .
      C Total          0        0.00000

          Root MSE             .     R-square            .
          Dep Mean      -0.80618     Adj R-sq            .
          C.V.                 .

NOTE: Model is not full rank. Least-squares solutions for the parameters are
      not unique. Some statistics will be misleading. A reported DF of 0 or B
      means that the estimate is biased.
      The following parameters have been set to 0, since the variables are a
      linear combination of other variables as shown.

      TEMP      = +894.0000 * INTERCEP
                              Parameter Estimates

                     Parameter      Standard    T for H0:
    Variable    DF    Estimate         Error   Parameter=0    Prob > |T|

    INTERCEP     B   -0.806180     .                 .             .
    TEMPERATURE 0            0     .                 .             .
```

```
                                 SAS     10:58 Wednesday, October 26, 1988
                                                                         3

-------------------------------- CADMIUM -------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                          Analysis of Variance

                               Sum of         Mean
      Source          DF      Squares       Square      F Value       Prob>F

      Model            1     15.67397     15.67397       19.186       0.0001
      Error           49     40.03007      0.81694
      C Total         50     55.70404

          Root MSE       0.90385     R-square       0.2814
          Dep Mean       0.47109     Adj R-sq       0.2667
          C.V.         191.86197

                          Parameter Estimates

                     Parameter      Standard    T for H0:
    Variable   DF     Estimate         Error   Parameter=0    Prob > |T|

    INTERCEP    1    -6.174456    1.52244774        -4.056        0.0002
    TEMPERATURE 1     0.008353    0.00190704         4.380        0.0001
                                                                         4

-------------------------------- CHROMIUM ------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                          Analysis of Variance

                               Sum of         Mean
      Source          DF      Squares       Square      F Value       Prob>F

      Model            1      3.06664      3.06664        3.896       0.0547
      Error           44     34.63548      0.78717
      C Total         45     37.70212

          Root MSE       0.88723     R-square       0.0813
          Dep Mean      -0.76892     Adj R-sq       0.0605
          C.V.        -115.38548

                          Parameter Estimates

                     Parameter      Standard    T for H0:
    Variable   DF     Estimate         Error   Parameter=0    Prob > |T|

    INTERCEP    1    -4.471912    1.88065265        -2.378        0.0218
    TEMPERATURE 1     0.004688    0.00237507         1.974        0.0547
```

```
----------------------------------- COBALT ----------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                              Analysis of Variance

                                  Sum of         Mean
      Source             DF      Squares       Square      F Value        Prob>F

      Model               1      0.97638      0.97638        2.826        0.1913
      Error               3      1.03649      0.34550
      C Total             4      2.01287

          Root MSE       0.58779     R-square       0.4851
          Dep Mean      -1.26537     Adj R-sq       0.3134
          C.V.         -46.45198

                              Parameter Estimates

                        Parameter        Standard    T for H0:
     Variable    DF      Estimate           Error   Parameter=0    Prob > |T|

     INTERCEP     1      5.704706      4.15452880         1.373        0.2633
     TEMPERATURE  1     -0.009548      0.00567973        -1.681        0.1913
                                                                                6

----------------------------------- COPPER ----------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                              Analysis of Variance

                                  Sum of         Mean
      Source             DF      Squares       Square      F Value        Prob>F

      Model               1      2.09957      2.09957        6.321        0.0165
      Error              36     11.95715      0.33214
      C Total            37     14.05671

          Root MSE       0.57632     R-square       0.1494
          Dep Mean      -0.80271     Adj R-sq       0.1257
          C.V.         -71.79659

                              Parameter Estimates

                        Parameter        Standard    T for H0:
     Variable    DF      Estimate           Error   Parameter=0    Prob > |T|

     INTERCEP     1     -3.655865      1.13865455        -3.211        0.0028
     TEMPERATURE  1      0.003649      0.00145116         2.514        0.0165
```

```
----------------------------------- IRON -----------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                              Analysis of Variance

                                 Sum of         Mean
      Source          DF        Squares       Square      F Value       Prob>F

      Model            1        1.26677      1.26677        5.008       0.0603
      Error            7        1.77066      0.25295
      C Total          8        3.03743

          Root MSE        0.50294     R-square       0.4171
          Dep Mean       -1.61514     Adj R-sq       0.3338
          C.V.          -31.13930

                              Parameter Estimates

                       Parameter       Standard    T for H0:
    Variable    DF      Estimate          Error   Parameter=0    Prob > |T|

    INTERCEP     1      5.461022     3.16647640         1.725        0.1282
    TEMPERATURE 1      -0.009535     0.00426087        -2.238        0.0603
                                                                             8

----------------------------------- LEAD -----------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                              Analysis of Variance

                                 Sum of         Mean
      Source          DF        Squares       Square      F Value       Prob>F

      Model            1       13.02875     13.02875       17.329       0.0001
      Error           54       40.59989      0.75185
      C Total         55       53.62864

          Root MSE        0.86709     R-square       0.2429
          Dep Mean        0.19794     Adj R-sq       0.2289
          C.V.          438.05343

                              Parameter Estimates

                       Parameter       Standard    T for H0:
    Variable    DF      Estimate          Error   Parameter=0    Prob > |T|

    INTERCEP     1     -5.837558     1.45448685        -4.013        0.0002
    TEMPERATURE 1       0.007574     0.00181956         4.163        0.0001
```

```
                                   SAS     10:58 Wednesday, October 26, 1988
                                                                           9

---------------------------------- MAGNESIUM ---------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                             Analysis of Variance

                                Sum of         Mean
      Source          DF       Squares       Square      F Value       Prob>F

      Model            1       0.80844      0.80844        4.243       0.0784
      Error            7       1.33370      0.19053
      C Total          8       2.14214

          Root MSE       0.43650     R-square       0.3774
          Dep Mean      -1.77521     Adj R-sq       0.2885
          C.V.         -24.58839

                             Parameter Estimates

                      Parameter        Standard    T for H0:
    Variable    DF     Estimate           Error   Parameter=0    Prob > |T|

    INTERCEP     1     3.877705      2.74813525         1.411        0.2011
    TEMPERATURE  1    -0.007617      0.00369794        -2.060        0.0784

                                                                          10

---------------------------------- MANGANESE ---------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                             Analysis of Variance

                                Sum of         Mean
      Source          DF       Squares       Square      F Value       Prob>F

      Model            1       1.28089      1.28089        1.618       0.2440
      Error            7       5.54060      0.79151
      C Total          8       6.82149

          Root MSE       0.88967     R-square       0.1878
          Dep Mean      -1.50404     Adj R-sq       0.0717
          C.V.         -59.15227

                             Parameter Estimates

                      Parameter        Standard    T for H0:
    Variable    DF     Estimate           Error   Parameter=0    Prob > |T|

    INTERCEP     1     5.611448      5.60128159         1.002        0.3498
    TEMPERATURE  1    -0.009588      0.00753718        -1.272        0.2440
```

```
                                        SAS      10:58 Wednesday, October 26, 1988
                                                                               11
----------------------------------- MERCURY ----------------------------------
Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                             Analysis of Variance

                                 Sum of         Mean
      Source            DF      Squares        Square      F Value       Prob>F

      Model              1      0.23423       0.23423          .             .
      Error              0       .              .
      C Total            1      0.23423

          Root MSE         .             R-square       1.0000
          Dep Mean        1.64679        Adj R-sq        .
          C.V.             .

                             Parameter Estimates

                       Parameter       Standard     T for H0:
    Variable    DF      Estimate          Error    Parameter=0     Prob > |T|

    INTERCEP     1    -22.526355          .              .              .
    TEMPERATURE  1      0.031111          .              .              .

                                                                               12
----------------------------------- NICKEL -----------------------------------
Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                             Analysis of Variance

                                 Sum of         Mean
      Source            DF      Squares        Square      F Value       Prob>F

      Model              1      1.38329       1.38329        1.983         0.1684
      Error             33     23.01782       0.69751
      C Total           34     24.40111

          Root MSE        0.83517        R-square       0.0567
          Dep Mean       -0.33818        Adj R-sq       0.0281
          C.V.         -246.96053

                             Parameter Estimates

                       Parameter       Standard     T for H0:
    Variable    DF      Estimate          Error    Parameter=0     Prob > |T|

    INTERCEP     1     -2.768912     1.73182399         -1.599         0.1194
    TEMPERATURE  1      0.003011     0.00213795          1.408         0.1684
```

```
                                   SAS     10:58 Wednesday, October 26, 1988
                                                                          13

----------------------------------- SILVER ----------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                              Analysis of Variance

                                Sum of         Mean
      Source           DF      Squares       Square      F Value       Prob>F

      Model             1      0.50967      0.50967        0.270       0.6550
      Error             2      3.77312      1.88656
      C Total           3      4.28278

          Root MSE       1.37352      R-square       0.1190
          Dep Mean      -1.34546      Adj R-sq      -0.3215
          C.V.        -102.08518

                              Parameter Estimates

                       Parameter      Standard    T for H0:
    Variable    DF      Estimate         Error   Parameter=0    Prob > |T|

    INTERCEP     1     40.064201   79.67255240         0.503        0.6650
    TEMPERATURE  1     -0.054594    0.10503572        -0.520        0.6550

                                                                          14

------------------------------------- TIN -----------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                              Analysis of Variance

                                Sum of         Mean
      Source           DF      Squares       Square      F Value       Prob>F

      Model             1      1.00286      1.00286        2.575       0.1597
      Error             6      2.33649      0.38941
      C Total           7      3.33935

          Root MSE       0.62403      R-square       0.3003
          Dep Mean      -0.30268      Adj R-sq       0.1837
          C.V.        -206.16772

                              Parameter Estimates

                       Parameter      Standard    T for H0:
    Variable    DF      Estimate         Error   Parameter=0    Prob > |T|

    INTERCEP     1      6.057114    3.96917722         1.526        0.1778
    TEMPERATURE  1     -0.008596    0.00535637        -1.605        0.1597
```

```
------------------------------------ ZINC ------------------------------------

Model: MODEL1
Dependent Variable: LOG10 OF EMISSION RATE

                         Analysis of Variance

                          Sum of         Mean
   Source         DF     Squares       Square      F Value       Prob>F

   Model           1     1.84403      1.84403        1.707       0.2009
   Error          31    33.47905      1.07997
   C Total        32    35.32308

       Root MSE       1.03922     R-square       0.0522
       Dep Mean      -0.39811     Adj R-sq       0.0216
       C.V.        -261.03528

                         Parameter Estimates

                     Parameter       Standard    T for H0:
  Variable    DF      Estimate          Error   Parameter=0    Prob > |T|

  INTERCEP     1     -3.177499     2.13469679        -1.489        0.1467
  TEMPERATURE 1       0.003547     0.00271419         1.307        0.2009
```

```
                                          SAS    17:57 Tuesday, November 1, 1988   1
------------------------------ POLLUTANT=BENZENE ------------------------------

         INCIN    REF      FEED      EMISSION    EMISSION      LOG10 OF       TEMPERATURE
  OBS     ID      NO.     (MG/H)      (MG/H)       RATE     EMISSION RATE     IN CELSIUS

   1      27      R15      587          322       54.855       1.73922            766
   2      27      R15      558          784      100.000       2.00000            778
   3      27      R15      466           97       20.815       1.31839            768

--------------------- POLLUTANT=CARBON TETRACHLORIDE ----------------------

         INCIN    REF      FEED      EMISSION    EMISSION      LOG10 OF       TEMPERATURE
  OBS     ID      NO.     (MG/H)      (MG/H)       RATE     EMISSION RATE     IN CELSIUS

   4      27      R15      67.8         14       20.6490       1.31490            768

--------------------- POLLUTANT=METHYLENE CHLORIDE ----------------------

         INCIN    REF      FEED      EMISSION    EMISSION      LOG10 OF       TEMPERATURE
  OBS     ID      NO.     (MG/H)      (MG/H)       RATE     EMISSION RATE     IN CELSIUS

   5      26      R14     58255         338      0.58021      -0.23642            916
   6      26      R14     6800          158      2.32353       0.36615            916
   7      26      R14     20244         958      4.73227       0.67507            903
   8      26      R14     6025          303      5.02905       0.70149            813
   9      26      R14     10701         828      7.73759       0.88861            894
  10      26      R14     10915         874      8.00733       0.90349            834
  11      27      R15     2060           99      4.80583       0.68177            766
  12      27      R15     1530           87      5.68627       0.75483            778
  13      27      R15     881            25      2.83768       0.45296            768

---------------------------- POLLUTANT=TOLUENE ------------------------------

         INCIN    REF      FEED      EMISSION    EMISSION      LOG10 OF       TEMPERATURE
  OBS     ID      NO.     (MG/H)      (MG/H)       RATE     EMISSION RATE     IN CELSIUS

  14      26      R14     445745       3972      0.89109      -0.05008            916
  15      26      R14     335673       3556      1.05936       0.02505            916
  16      26      R14     630800      16120      2.55549       0.40747            903
  17      26      R14     387964      14230      3.66787       0.56441            813
  18      26      R14     397155      13560      3.41428       0.53330            894
  19      26      R14     940909      20080      2.13411       0.32922            834
  20      27      R15     16900          19      0.11243      -0.94913            766
  21      27      R15     20460          35      0.17107      -0.76684            778
  22      27      R15     28250         148      0.52389      -0.28076            768
```

```
                                  SAS   17:57 Tuesday, November 1, 1988   2

------------------------------ POLLUTANT=ARSENIC ------------------------------

       INCIN    REF     FEED      EMISSION    EMISSION      LOG10 OF      TEMPERATURE
OBS     ID      NO.    (MG/H)      (MG/H)       RATE      EMISSION RATE   IN CELSIUS

  1      1      R1     71             0.43      0.6056     -0.21779          704
  2      1      R1     71             0.36      0.5070     -0.29496          704
  3      1      R1     49             2.20      4.4898      0.65223          816
  4      1      R1     49             0.33      0.6735     -0.17168          816
  5      1      R1     64             7.40     11.5625      1.06305          927
  6      1      R1     64             1.10      1.7188      0.23521          927
  7     20      R8     126236        19.00      0.0151     -1.82243          761
  8     20      R8     149026        68.00      0.0456     -1.34075          748
  9     20      R9     185856       198.00      0.1065     -0.97251          726
 10     20      R9     166455       137.00      0.0823     -1.08458          747
 11     20      R9     193116       314.00      0.1626     -0.78889          774
 12     26      R14    9900         498.00      5.0303      0.70159          903
 13     26      R14    9300         462.00      4.9677      0.69616          889
 14     26      R14    8800         446.00      5.0682      0.70485          889
 15     26      R14    7800         394.00      5.0513      0.70340          834
 16     26      R14    7600         940.00     12.3684      1.09231          896
 17     26      R14    5300         180.00      3.3962      0.53100          813
 18     26      R14    6900         470.00      6.8116      0.83325          894
 19     27      R15    23500         30.70      0.1306     -0.88393          766
 20     27      R15    28400         26.10      0.0919     -1.03668          768
 21     27      R15    24300         23.70      0.0975     -1.01086          768
 22     28      R16    2200           4.00      0.1818     -0.74036          805
 23     28      R16    1400           2.00      0.1429     -0.84510          901
 24     28      R16    1400           4.00      0.2857     -0.54407          814


----------------------------- POLLUTANT=BERYLLIUM -----------------------------

       INCIN    REF     FEED      EMISSION    EMISSION      LOG10 OF      TEMPERATURE
OBS     ID      NO.    (MG/H)      (MG/H)       RATE      EMISSION RATE   IN CELSIUS

 25     26      R14     640           1        0.15625     -0.80618          894
```

```
------------------------------ POLLUTANT=CADMIUM ------------------------------

        INCIN   REF     FEED     EMISSION   EMISSION      LOG10 OF      TEMPERATURE
 OBS     ID     NO.    (MG/H)     (MG/H)      RATE     EMISSION RATE    IN CELSIUS

  26      1     R1     732          0.07     0.0096      -2.01941           704
  27      1     R1     732          1.00     0.1366      -0.86451           704
  28      1     R1     849         32.50     3.8280       0.58298           816
  29      1     R1     849          7.00     0.8245      -0.08381           816
  30      1     R1     945        169.00    17.8836       1.25245           927
  31      1     R1     945        382.00    40.4233       1.60663           927
  32     10     R3     4264       238.00     5.5816       0.74676           760
  33     10     R3     3130         1.00     0.0319      -1.49554           760
  34     10     R3     2722        21.00     0.7715      -0.11267           760
  35     10     R3     1361        41.00     3.0125       0.47893           760
  36     10     R3     1814        15.00     0.8269      -0.08255           760
  37     10     R3     1361        32.00     2.3512       0.37129           760
  38     10     R4     7200         7.30     0.1014      -0.99401           760
  39     11     R3     6804        27.00     0.3968      -0.40140           766
  40     12     R3     134174      29.00     0.0216      -1.66527           760
  41     12     R3     124694      33.00     0.0265      -1.57733           760
  42     12     R3     106006      29.00     0.0274      -1.56293           760
  43     13     R5     388000    2937.00     0.7570      -0.12093           733
  44     14     R5     696000    2086.00     0.2997      -0.52329           643
  45     15     R5     670400     122.00     0.0182      -1.73997           787
  46     19     R7     525          0.50     0.0952      -1.02119           788
  47     20     R8     45562      730.00     1.6022       0.20472           761
  48     20     R8     63753     2100.00     3.2940       0.51772           748
  49     20     R9     76032     1658.00     2.1807       0.33859           726
  50     20     R9     52002     2696.00     5.1844       0.71470           747
  51     20     R9     47190     1356.00     2.8735       0.45841           774
  52     25     R13    1200       510.00    42.5000       1.62839           829
  53     25     R13    1900       383.00    20.1579       1.30445           829
  54     25     R13    2200       514.00    23.3636       1.36854           826
  55     25     R13    1800       716.00    39.7778       1.59964           797
  56     26     R14    12000     1799.00    14.9917       1.17585           903
  57     26     R14    11000     1779.00    16.1727       1.20878           889
  58     26     R14    11000     2435.00    22.1364       1.34511           889
  59     26     R14    11000     2564.00    23.3091       1.36753           834
  60     26     R14    13700     3200.00    23.3577       1.36843           896
  61     26     R14    9800      1900.00    19.3878       1.28753           813
  62     26     R14    11300     2500.00    22.1239       1.34486           894
  63     27     R15    5900       240.00     4.0678       0.60936           766
  64     27     R15    7400       237.00     3.2027       0.50552           768
  65     27     R15    6800       339.00     4.9853       0.69769           768
  66     28     R16    4900      1029.00    21.0000       1.32222           676
  67     28     R16    7100      1335.00    18.8028       1.27422           799
  68     28     R16    6600      1005.00    15.2273       1.18262           718
  69     28     R16    7600      1775.00    23.3553       1.36838           805
  70     28     R16    7700      2018.00    26.2078       1.41843           815
  71     28     R16    7600      1153.00    15.1711       1.18102           906
  72     28     R16    8100      1696.00    20.9383       1.32094           901
  73     28     R16    8000      1370.00    17.1250       1.23363           774
```

```
----------------------------- POLLUTANT=CADMIUM ------------------------------
                                  (continued)

      INCIN   REF     FEED     EMISSION    EMISSION       LOG10 OF       TEMPERATURE
OBS    ID     NO.    (MG/H)     (MG/H)       RATE      EMISSION RATE    IN CELSIUS

 74    28     R16     8200       1720      20.9756        1.32171           814
 75    28     R16     8500       1814      21.3412        1.32922           766
 76    28     R16     8600       1541      17.9186        1.25330           932
```

```
------------------------------ POLLUTANT=CHROMIUM ------------------------------

         INCIN   REF    FEED        EMISSION   EMISSION      LOG10 OF       TEMPERATURE
  OBS     ID     NO.    (MG/H)        (MG/H)     RATE     EMISSION RATE    IN CELSIUS

   77      1     R1     8488            7.3    0.08600      -1.06548           704
   78      1     R1     6364            7.0    0.10999      -0.95863           816
   79      1     R1     7089           47.0    0.66300      -0.17849           927
   80     10     R3     14742         108.0    0.73260      -0.13513           760
   81     10     R3     10750           4.0    0.03721      -1.42935           760
   82     10     R3     9389            9.0    0.09586      -1.01838           760
   83     10     R3     12701          31.0    0.24408      -0.61248           760
   84     10     R3     18144         215.0    1.18496       0.07371           760
   85     10     R3     13608          30.0    0.22046      -0.65667           760
   86     10     R4     78000           5.9    0.00756      -2.12124           760
   87     11     R3     33113         517.0    1.56132       0.19349           766
   88     12     R3     115667        151.0    0.13055      -0.88423           760
   89     12     R3     107502        151.0    0.14046      -0.85244           760
   90     12     R3     91400         188.0    0.20569      -0.68679           760
   91     13     R5     4268000      6853.0    0.16057      -0.79434           733
   92     14     R5     8700000     28012.0    0.32198      -0.49218           643
   93     15     R5     1843600       263.0    0.01427      -1.84571           787
   94     19     R7     4600           50.0    1.08696       0.03621           788
   95     19     R7     4075           25.0    0.61350      -0.21219           788
   96     19     R7     3911           18.0    0.46024      -0.33702           788
   97     20     R8     72314         414.0    0.57250      -0.24222           761
   98     20     R8     104103        204.0    0.19596      -0.70783           748
   99     20     R9     195624       1280.0    0.65432      -0.18421           726
  100     20     R9     176904       6018.0    3.40185       0.53171           747
  101     20     R9     208362          7.0    0.00336      -2.47372           774
  102     24     R12    2039824         2.0    0.00100      -3.00000           785
  103     24     R12    2379987         2.0    0.00100      -3.00000           777
  104     24     R12    2409924         3.0    0.00100      -3.00000           744
  105     24     R12    1867521         2.0    0.00100      -3.00000           761
  106     25     R13    131000        739.0    0.56412      -0.24863           829
  107     25     R13    141000        204.0    0.14468      -0.83959           829
  108     25     R13    161000       1880.0    1.16770       0.06733           823
  109     25     R13    123000        218.0    0.17724      -0.75145           826
  110     25     R13    137000        444.0    0.32409      -0.48934           823
  111     25     R13    189000        251.0    0.13280      -0.87679           826
  112     25     R13    152000        256.0    0.16842      -0.77360           797
  113     26     R14    105000        417.0    0.39714      -0.40105           903
  114     26     R14    112000       3086.0    2.75536       0.44018           889
  115     26     R14    109000       2342.0    2.14862       0.33216           889
  116     26     R14    110000        747.0    0.67909      -0.16807           834
  117     26     R14    108000        470.0    0.43519      -0.36133           896
  118     26     R14    88100         290.0    0.32917      -0.48258           813
  119     26     R14    113000       1300.0    1.15044       0.06086           894
  120     27     R15    255000        748.0    0.29333      -0.53264           766
  121     27     R15    316000        940.0    0.29747      -0.52656           768
  122     27     R15    277000        475.0    0.17148      -0.76579           768
```

```
------------------------------ POLLUTANT=COBALT ------------------------------

       INCIN   REF     FEED     EMISSION   EMISSION       LOG10 OF      TEMPERATURE
OBS     ID     NO.    (MG/H)     (MG/H)      RATE      EMISSION RATE    IN CELSIUS

123     10     R4     10200         0.75    0.00735       -2.13354          760
124     14     R5     522000     1490.00    0.28544       -0.54448          643
125     20     R9     16500        10.00    0.06061       -1.21748          726
126     20     R9     13462        33.00    0.24513       -0.61060          747
127     20     R9     13237         2.00    0.01511       -1.82076          774
```

```
                                         SAS    17:57 Tuesday, November 1, 1988   7
------------------------------ POLLUTANT=COPPER --------------------------------

        INCIN   REF   FEED          EMISSION   EMISSION      LOG10 OF      TEMPERATURE
  OBS    ID     NO.   (MG/H)         (MG/H)      RATE     EMISSION RATE    IN CELSIUS

  128     1     R1    168296             94    0.05585      -1.25295          704
  129     1     R1    168296             64    0.03803      -1.41989          704
  130     1     R1    178188            372    0.20877      -0.68034          816
  131     1     R1    178188            139    0.07801      -1.10786          816
  132     1     R1    226855            847    0.37337      -0.42786          927
  133     1     R1    226855           2450    1.07999       0.03342          927
  134    10     R3    103012            166    0.16115      -0.79278          760
  135    10     R3    75252              10    0.01329      -1.87652          760
  136    10     R3    65726              35    0.05325      -1.27367          760
  137    10     R3    64411              71    0.11023      -0.95770          760
  138    10     R3    92080              75    0.08145      -1.08910          760
  139    10     R3    69854             102    0.14602      -0.83559          760
  140    10     R4    300000             35    0.01167      -1.93305          760
  141    11     R3    159666             18    0.01127      -1.94794          766
  142    12     R3    393269            625    0.15892      -0.79881          760
  143    12     R3    365508            709    0.19398      -0.71225          760
  144    12     R3    310759            792    0.25486      -0.59370          760
  145    14     R5    13050000        47084    0.36080      -0.44274          643
  146    15     R5    2262600           263    0.01162      -1.93465          787
  147    19     R7    126500            125    0.09881      -1.00518          788
  148    19     R7    104750             25    0.02387      -1.62221          788
  149    19     R7    117511             44    0.03744      -1.42663          788
  150    20     R8    988570            347    0.03510      -1.45468          761
  151    20     R8    1229330           701    0.05702      -1.24395          748
  152    20     R9    1386000          2284    0.16479      -0.78307          726
  153    20     R9    1232010          4183    0.33953      -0.46913          747
  154    20     R9    1372140          1480    0.10786      -0.96714          774
  155    28     R16   425000           2063    0.48541      -0.31389          676
  156    28     R16   475000           2559    0.53874      -0.26862          799
  157    28     R16   429000           1790    0.41725      -0.37960          718
  158    28     R16   500000           5348    1.06960       0.02922          805
  159    28     R16   501000           3045    0.60778      -0.21625          815
  160    28     R16   449000           3796    0.84543      -0.07292          906
  161    28     R16   476000           5962    1.25252       0.09779          901
  162    28     R16   445000           2740    0.61573      -0.21061          774
  163    28     R16   457000           4049    0.88600      -0.05257          814
  164    28     R16   435000           3672    0.84414      -0.07359          766
  165    28     R16   479000           4512    0.94196      -0.02597          932
```

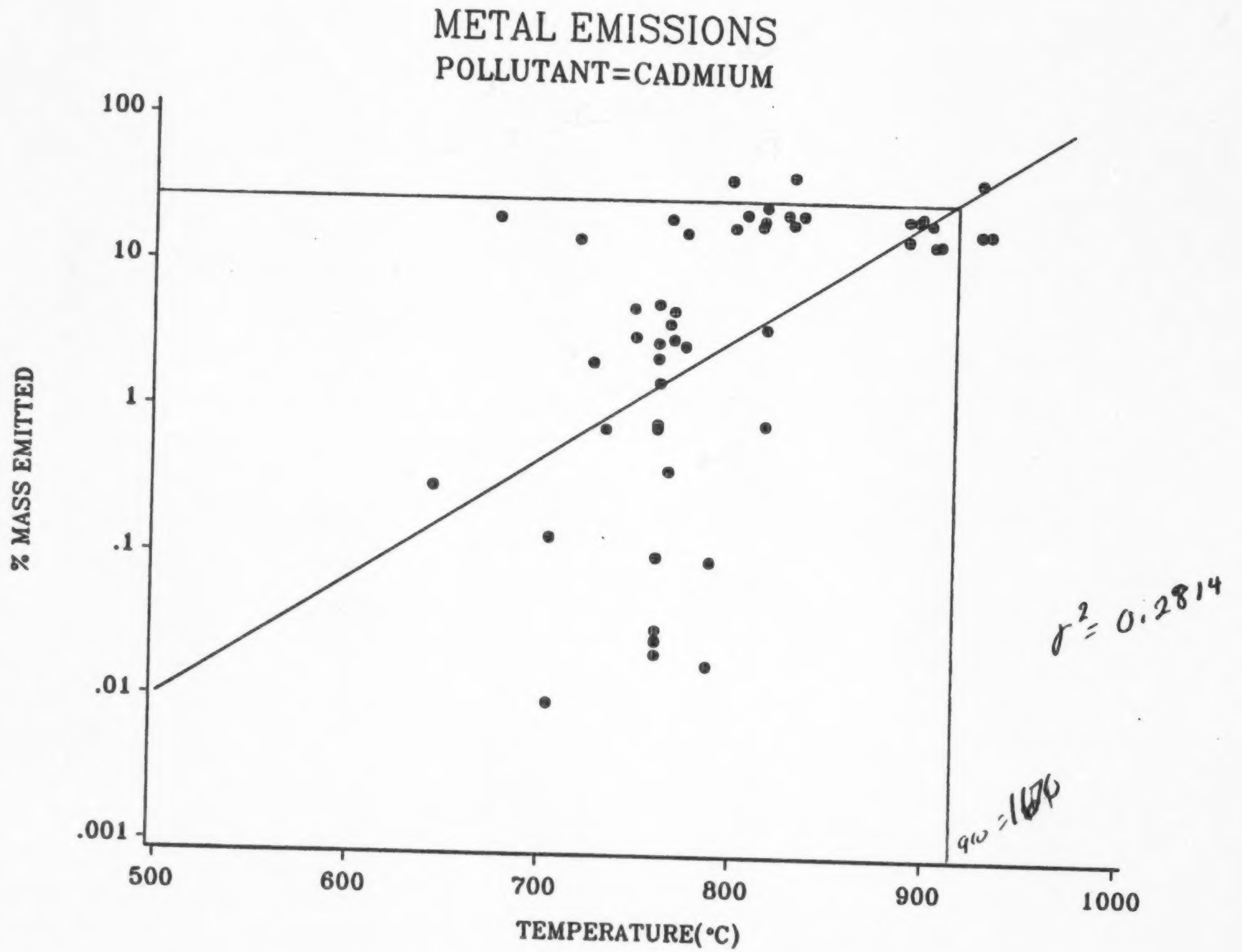
```
------------------------------ POLLUTANT=IRON ------------------------------

        INCIN   REF     FEED        EMISSION    EMISSION      LOG10 OF       TEMPERATURE
 OBS     ID     NO.    (MG/H)        (MG/H)       RATE     EMISSION RATE     IN CELSIUS

 166     10     R4    24600000         1530     0.00622      -2.20624            760
 167     13     R5    129980000       25899     0.01993      -1.70059            733
 168     14     R5    295800000      409750     0.13852      -0.85848            643
 169     15     R5    63688000         4249     0.00667      -2.17577            787
 170     20     R8    13543200         1739     0.01284      -1.89142            761
 171     20     R8    16920100         1445     0.00854      -2.06854            748
 172     20     R9    14572800        11880     0.08152      -1.08873            726
 173     20     R9    14239800        38704     0.27180      -0.56575            747
 174     20     R9    16214000         1695     0.01045      -1.98072            774

------------------------------ POLLUTANT=LEAD ------------------------------

        INCIN   REF   FEED        EMISSION    EMISSION      LOG10 OF       TEMPERATURE
 OBS     ID     NO.   (MG/H)       (MG/H)       RATE     EMISSION RATE     IN CELSIUS

 175      1     R1    42094           0.13     0.0010      -3.00000            704
 176      1     R1    42074          28.00     0.0665      -1.17686            704
 177      1     R1    44546         249.00     0.5590      -0.25261            816
 178      1     R1    44546         112.00     0.2514      -0.59959            816
 179      1     R1    47261        3704.00     7.8373       0.89417            927
 180      1     R1    47261        3633.00     7.6871       0.88576            927
 181     10     R3    34609         126.00     0.3641      -0.43882            760
 182     10     R3    25311          20.00     0.0790      -1.10228            760
 183     10     R3    22090           8.00     0.0362      -1.44111            760
 184     10     R3    6350          114.00     1.7953       0.25413            760
 185     10     R3    67586         594.00     0.8789      -0.05607            760
 186     10     R3    51256         490.00     0.9560      -0.01955            760
 187     10     R4    258000         82.00     0.0318      -1.49781            760
 188     11     R3    80287         649.00     0.8084      -0.09240            766
 189     12     R3    11567         308.00     2.6627       0.42533            760
 190     12     R3    10750         117.00     1.0884       0.03678            760
 191     12     R3    9163          279.00     3.0449       0.48357            760
 192     13     R5    6596000     36223.00     0.5492      -0.26030            733
 193     14     R5    8352000     67646.00     0.8099      -0.09155            643
 194     15     R5    4944200      2124.00     0.0430      -1.36694            787
 195     19     R7    37550         100.00     0.2663      -0.57461            788
 196     19     R7    28175          20.00     0.0710      -1.14883            788
 197     19     R7    33867          89.00     0.2628      -0.58039            788
 198     20     R8    130625        317.00     0.2427      -0.61497            761
 199     20     R8    188569       1260.00     0.6682      -0.17510            748
 200     20     R9    248160        691.00     0.2784      -0.55525            726
 201     20     R9    247860       4714.00     1.9019       0.27918            747
 202     20     R9    244420       2079.00     0.8506      -0.07028            774
 203     25     R13   67800       20400.00    30.0885       1.47840            829
 204     25     R13   76900       17900.00    23.2770       1.36693            829
 205     25     R13   67100       16100.00    23.9940       1.38010            823
 206     25     R13   51800       12100.00    23.3591       1.36846            826
```

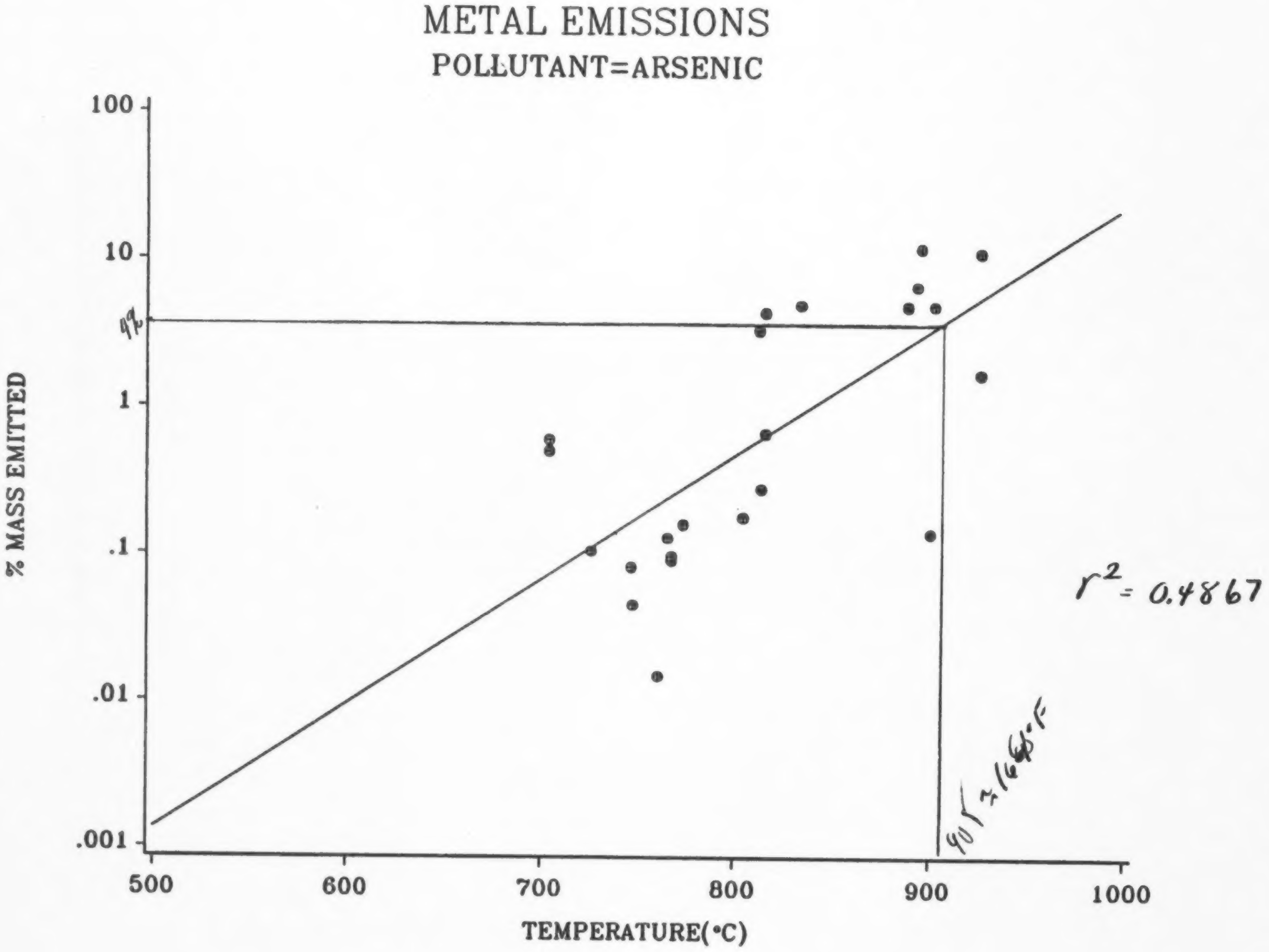
```
------------------------------- POLLUTANT=LEAD --------------------------------
                                  (continued)

          INCIN    REF      FEED      EMISSION    EMISSION       LOG10 OF      TEMPERATURE
OBS        ID      NO.     (MG/H)      (MG/H)       RATE      EMISSION RATE     IN CELSIUS

207        25      R13     71100        22300     31.3643        1.49644           823
208        25      R13     77600        33100     42.6546        1.62997           826
209        25      R13     67300        37300     55.4235        1.74369           797
210        26      R14     143000        4979      3.4818        0.54181           903
211        26      R14     134000        4222      3.1507        0.49841           889
212        26      R14     129000        3409      2.6426        0.42204           889
213        26      R14     134000        4178      3.1179        0.49386           834
214        26      R14     142000        8900      6.2676        0.79710           896
215        26      R14     95900         3000      3.1283        0.49530           813
216        26      R14     125000        5800      4.6400        0.66652           894
217        27      R15     269000         467      0.1736       -0.76044           766
218        27      R15     368000         519      0.1410       -0.85068           768
219        27      R15     416000         363      0.0873       -1.05919           768
220        28      R16     138000        7847      5.6862        0.75482           676
221        28      R16     186000       13711      7.3715        0.86756           799
222        28      R16     163000        8951      5.4914        0.73968           718
223        28      R16     187000       35682     19.0813        1.28061           805
224        28      R16     101000       20449     20.2465        1.30635           815
225        28      R16     276000       18273      6.6207        0.82090           906
226        28      R16     205000       49806     24.2956        1.38553           901
227        28      R16     201000       15481      7.7020        0.88660           774
228        28      R16     196000       20223     10.3179        1.01359           814
229        28      R16     209000       28819     13.7890        1.13953           766
230        28      R16     205000       22336     10.8956        1.03725           932


---------------------------- POLLUTANT=MAGNESIUM -----------------------------

         INCIN    REF       FEED       EMISSION    EMISSION      LOG10 OF      TEMPERATURE
   OBS    ID      NO.      (MG/H)       (MG/H)       RATE     EMISSION RATE    IN CELSIUS

   231    10      R4     1500000          198      0.01320      -1.87943          760
   232    13      R5     34920000        6319      0.01810      -1.74243          733
   233    14      R5     17400000       25628      0.14729      -0.83183          643
   234    15      R5     7290600          949      0.01302      -1.88550          787
   235    20      R8     3971000          372      0.00937      -2.02836          761
   236    20      R8     5595200           87      0.00155      -2.80830          748
   237    20      R9     5887200         1296      0.02201      -1.65730          726
   238    20      R9     5977800         1634      0.02733      -1.56329          747
   239    20      R9     5808000         1526      0.02627      -1.58047          774
```

F. 39.

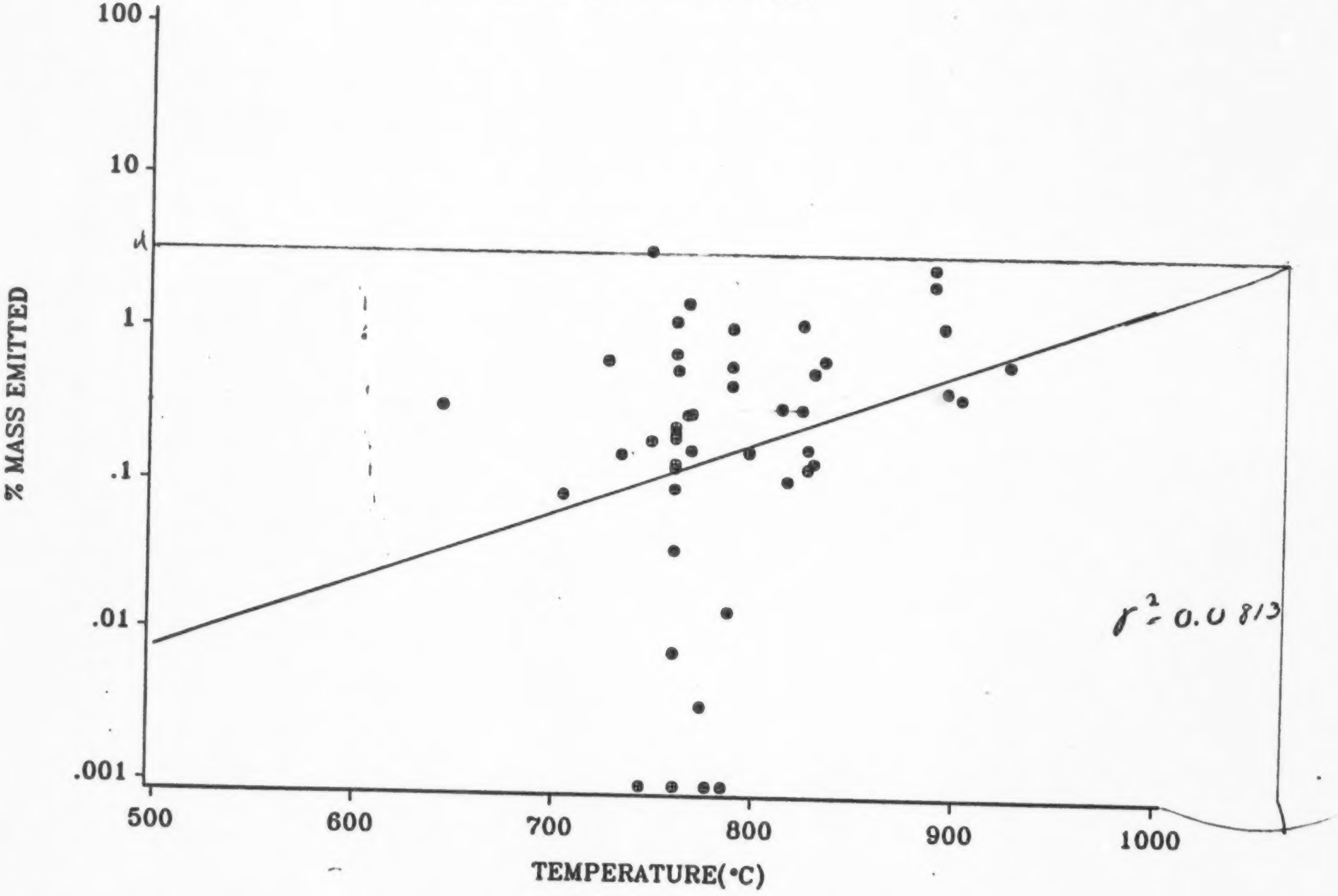
```
------------------------------ POLLUTANT=MANGANESE ------------------------------

         INCIN   REF   FEED        EMISSION   EMISSION      LOG10 OF      TEMPERATURE
  OBS     ID     NO.   (MG/H)       (MG/H)      RATE     EMISSION RATE    IN CELSIUS

  240     10     R4    780000         15.00    0.00192      -2.71600          760
  241     13     R5    13580000     1869.00    0.01376      -1.86129          733
  242     14     R5    4002000      4768.00    0.11914      -0.92394          643
  243     15     R5    2849200       432.00    0.01516      -1.81924          787
  244     20     R8    66462          52.00    0.07824      -1.10657          761
  245     20     R8    87694          62.00    0.07070      -1.15058          748
  246     20     R9    105864        180.00    0.17003      -0.76948          726
  247     20     R9    106677        690.00    0.64681      -0.18922          747
  248     20     R9    118580          0.00    0.00100      -3.00000          774

------------------------------ POLLUTANT=MERCURY ------------------------------

         INCIN     REF      FEED      EMISSION     EMISSION       LOG10 OF        TEMPERATURE
 OBS      ID       NO.     (MG/H)      (MG/H)        RATE      EMISSION RATE      IN CELSIUS

 249      11       R3       367          74        20.1635        1.30457            766
 250      19       R7       800         780        97.5000        1.98900            788
```

```
------------------------------ POLLUTANT=NICKEL -------------------------------

         INCIN   REF   FEED       EMISSION   EMISSION      LOG10 OF      TEMPERATURE
   OBS    ID     NO.   (MG/H)     (MG/H)       RATE      EMISSION RATE    IN CELSIUS

   251    14     R5    2436000     7152.0     0.2936      -0.53225          643
   252    19     R7    3075           7.5     0.2439      -0.61278          788
   253    19     R7    2900           7.5     0.2586      -0.58734          788
   254    20     R8    29887        537.0     1.7968       0.25449          761
   255    20     R8    50572        433.0     0.8562      -0.06742          748
   256    20     R9    86328         65.0     0.0753      -1.12324          726
   257    20     R9    59292       2820.0     4.7561       0.67725          747
   258    20     R9    471900         4.0     0.0010      -3.00000          774
   259    25     R13   14800        280.0     1.8919       0.27690          829
   260    25     R13   15800        204.0     1.2911       0.11097          829
   261    25     R13   14800       9900.0    66.8919       1.82537          823
   262    25     R13   8800         290.0     3.2955       0.51792          826
   263    25     R13   14900        111.0     0.7450      -0.12786          823
   264    25     R13   15000        280.0     1.8667       0.27107          826
   265    26     R14   110000       671.0     0.6100      -0.21467          903
   266    26     R14   120000      7378.0     6.1483       0.78876          889
   267    26     R14   116000      6186.0     5.3328       0.72695          889
   268    26     R14   116000      2059.0     1.7750       0.24920          834
   269    26     R14   107000      1800.0     1.6822       0.22589          896
   270    26     R14   100000       280.0     0.2800      -0.55284          813
   271    26     R14   116000      4200.0     3.6207       0.55879          894
   272    27     R15   1190000     7406.0     0.6224      -0.20596          766
   273    27     R15   1310000     6182.0     0.4719      -0.32614          768
   274    27     R15   1130000     4239.0     0.3751      -0.42582          768
   275    28     R16   161000       345.0     0.2143      -0.66901          676
   276    28     R16   135000       146.0     0.1081      -0.96598          799
   277    28     R16   127000       183.0     0.1441      -0.84135          718
   278    28     R16   118000        83.0     0.0703      -1.15280          805
   279    28     R16   83000        132.0     0.1590      -0.79850          815
   280    28     R16   227000       106.0     0.0467      -1.33072          906
   281    28     R16   238000       500.0     0.2101      -0.67761          901
   282    28     R16   180000       107.0     0.0594      -1.22589          774
   283    28     R16   201000       196.0     0.0975      -1.01094          814
   284    28     R16   164000       157.0     0.0957      -1.01894          766
   285    28     R16   177000       249.0     0.1407      -0.85177          932

------------------------------ POLLUTANT=SILVER -------------------------------

        INCIN    REF      FEED      EMISSION     EMISSION       LOG10 OF        TEMPERATURE
 OBS     ID      NO.     (MG/H)      (MG/H)        RATE      EMISSION RATE      IN CELSIUS

 286     10      R3      4717         0.008      0.00100       -3.00000            760
 287     10      R4      17400        7.200      0.04138       -1.38322            760
 288     11      R3      2722         5.000      0.18369       -0.73592            766
 289     20      R8      4761        26.000      0.54610       -0.26272            748
```


METAL EMISSIONS
POLLUTANT=CADMIUM

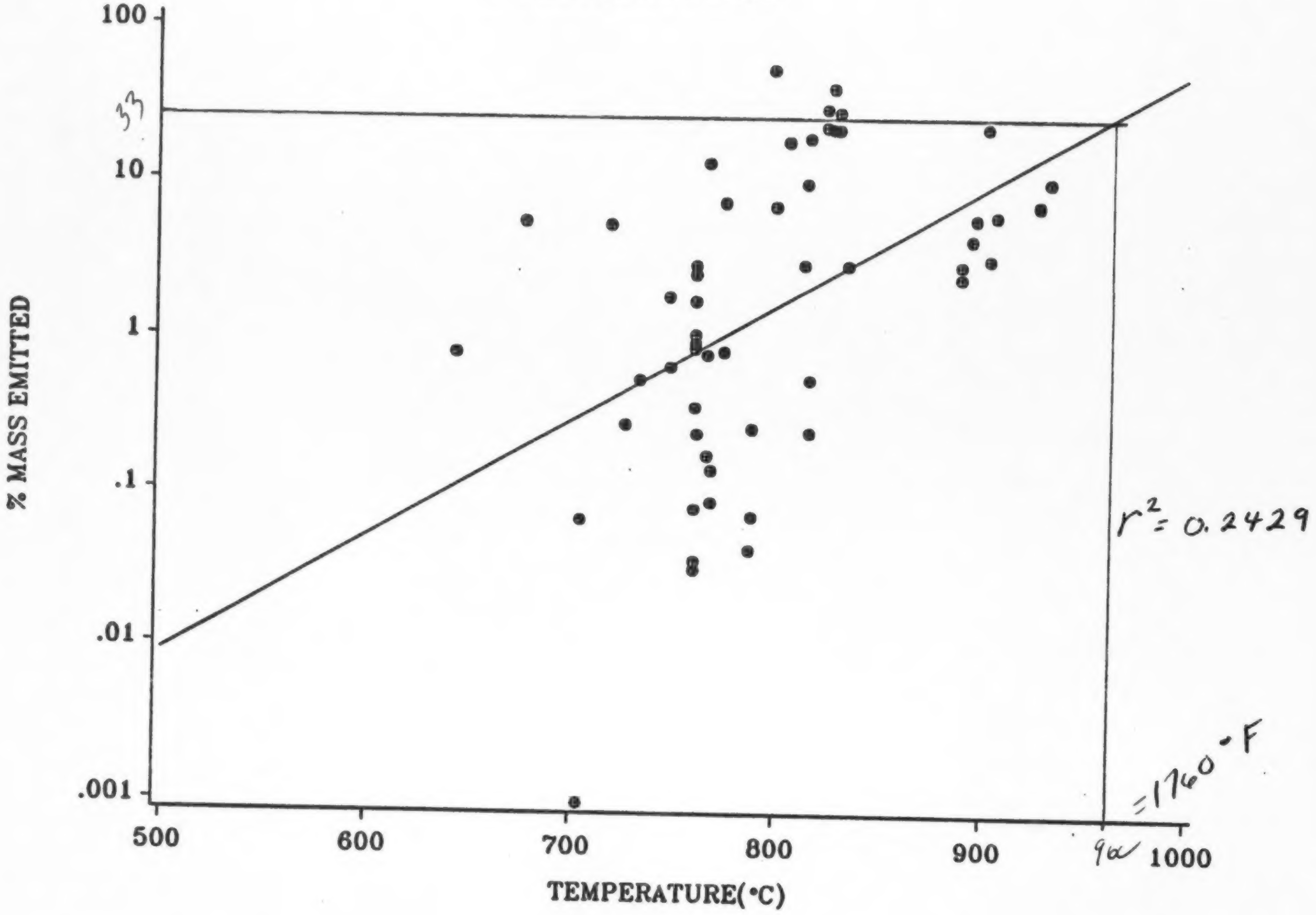

METAL EMISSIONS
POLLUTANT=ARSENIC
% MASS EMITTED
100
10
4%
1
.1
.01
.001
500
600
700
800
900
1000
TEMPERATURE(°C)
905 = 1661°F
r^2 = 0.4867

METAL EMISSIONS
POLLUTANT=CHROMIUM

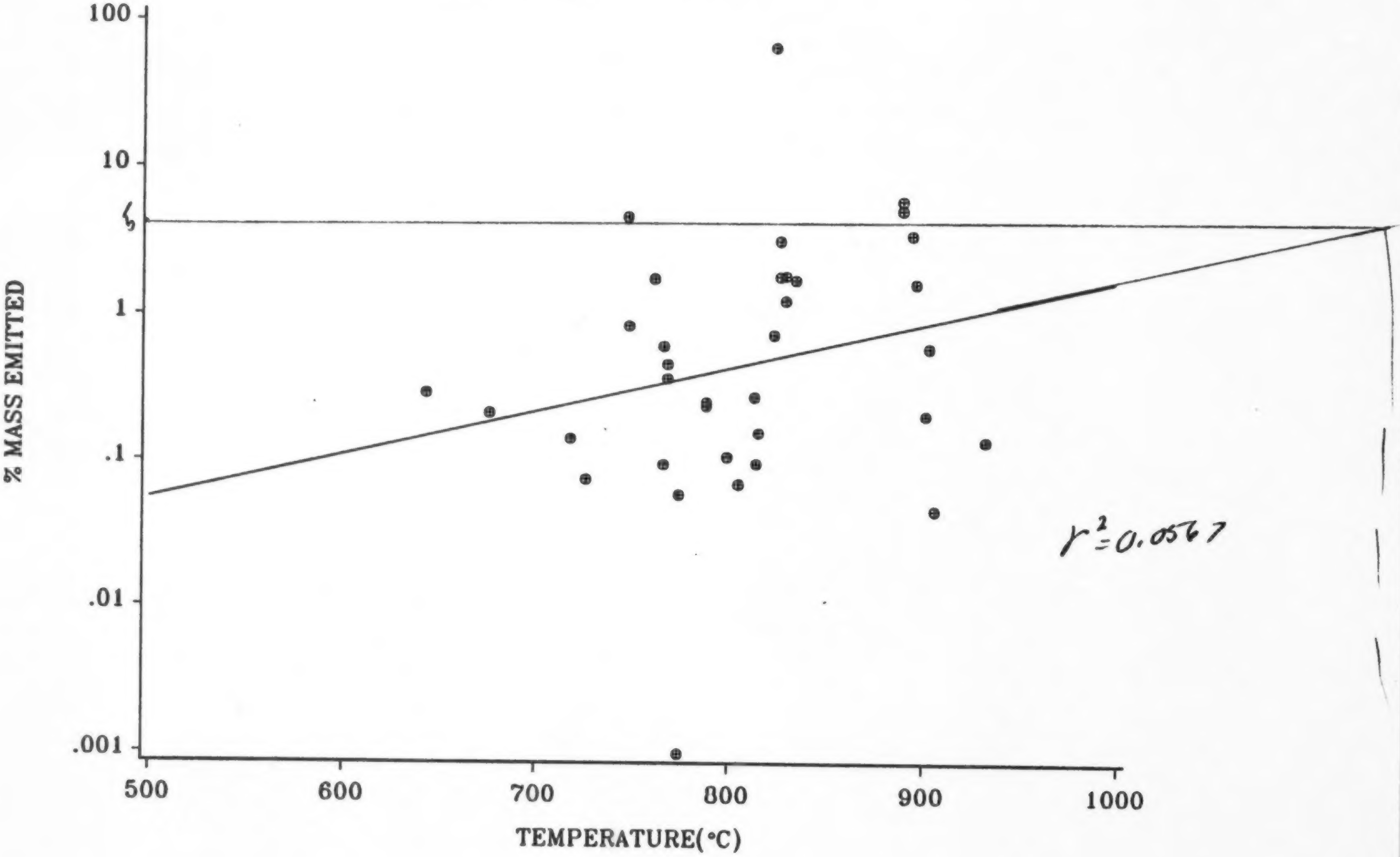


F 44-

METAL EMISSIONS
POLLUTANT=LEAD



METAL EMISSIONS
POLLUTANT=NICKEL



F_46-

```
------------------------------ POLLUTANT=TIN ------------------------------

        INCIN   REF     FEED      EMISSION   EMISSION      LOG10 OF      TEMPERATURE
  OBS    ID     NO.    (MG/H)      (MG/H)      RATE     EMISSION RATE    IN CELSIUS

  290    13     R5    5820000      12638     0.21715      -0.66324           733
  291    14     R5    4350000      71222     1.63729       0.21412           643
  292    15     R5    2095000        555     0.02649      -1.57689           787
  293    20     R8    51205           87     0.16991      -0.76979           761
  294    20     R8    76396          391     0.51181      -0.29089           748
  295    20     R9    123288        2678     2.17215       0.33689           726
  296    20     R9    101574        3375     3.32270       0.52149           747
  297    20     R9    106238         681     0.64101      -0.19313           774

------------------------------ POLLUTANT=ZINC ------------------------------

        INCIN   REF     FEED      EMISSION   EMISSION      LOG10 OF      TEMPERATURE
  OBS    ID     NO.    (MG/H)      (MG/H)      RATE     EMISSION RATE    IN CELSIUS

  298     1     R1    137883          58     0.0421       -1.37608           816
  299     1     R1    146510         180     0.1229       -0.91059           927
  300     1     R1    146510         495     0.3379       -0.47126           927
  301    10     R3    986301         185     0.0188       -1.72684           760
  302    10     R3    720448          19     0.0026       -2.57885           760
  303    10     R3    629230          34     0.0054       -2.26733           760
  304    10     R3    137440          98     0.0713       -1.14689           760
  305    10     R3    197315         147     0.0745       -1.12784           760
  306    10     R3    149687         170     0.1136       -0.94474           760
  307    10     R4    576000          64     0.0111       -1.95424           760
  308    11     R3    125646         649     0.5165       -0.28690           766
  309    12     R3    323868         750     0.2316       -0.63531           760
  310    12     R3    301007        3125     1.0382        0.01627           760
  311    12     R3    255919        3750     1.4653        0.16593           760
  312    13     R5    5820000      57316     0.9848       -0.00665           733
  313    14     R5    19140000    106684     0.5574       -0.25384           643
  314    15     R5    8380000       1617     0.0193       -1.71453           787
  315    20     R8    1270720       1317     0.1036       -0.98446           761
  316    20     R8    1778090       1000     0.0562       -1.24995           748
  317    20     R9    1734480       3731     0.2151       -0.66734           726
  318    20     R9    1807920       5304     0.2934       -0.53258           747
  319    20     R9    1848880       1153     0.0624       -1.20508           774
  320    28     R16   344000       15144     4.4023        0.64368           676
  321    28     R16   404000       17331     4.2899        0.63244           799
  322    28     R16   375000       11837     3.1565        0.49921           718
  323    28     R16   424000       13035     3.0743        0.48775           805
  324    28     R16   405000       31299     7.7281        0.88808           815
  325    28     R16   357000       20721     5.8042        0.76374           906
  326    28     R16   378000       32633     8.6331        0.93617           901
  327    28     R16   366000       27546     7.5262        0.87658           774
  328    28     R16   359000       35300     9.8329        0.99268           814
  329    28     R16   350000       34888     9.9680        0.99861           766
  330    28     R16   371000       37310    10.0566        1.00245           932
```